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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 234

Contribution from the Forest Service
HENRY S. GRAVES, Forester

Washington, D. C. PROFESSIONAL PAPER July 12, 1915

UTILIZATION AND MANAGEMENT OF LODGEPOLE PINE IN THE ROCKY MOUNTAINS

By

D. T. MASON, Assistant District Forester, District 1

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BULLETIN OF THE
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OWNERSHIP AND SUPPLY.

Lodgepole pine (*Pinus contorta*) is the most important timber tree of that portion of the Rocky Mountains lying between northern Colorado and central Montana. Once considered practically worthless, it now brings the Federal Government a revenue of from $10 to $100 an acre in National Forest timber sales.

By far the greater part of the present supply of lodgepole pine is included within the National Forests. As will be seen from Table 1, it is the most important tree species on a number of Forests in Montana, Wyoming, Colorado, Idaho, and Utah, forming in such cases from 30 to 92 per cent of the total stand of timber, and is of commercial though not primary importance on still other Forests in these States and in Washington, Oregon, and California. The principal privately owned bodies of lodgepole pine of any size are in Montana, where the State and the Northern Pacific Railroad hold considerable tracts. The total stand of lodgepole pine on those Forests where it is commercially important has been estimated at about 40 billion board feet (Table 1). Figure 1 shows by National Forests the regions where lodgepole pine occurs, either commercially or botanically.

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TABLE 1.—*Estimated stand of lodgepole pine on the National Forests in which it is of commercial importance.*

State.	Stand of lodgepole pine, 1,000 board feet.	Per cent of total stand.
MONTANA.		
Forests in which lodgepole pine is most important species:		
Missoula	2,464,000	80
Beaverhead	1,132,000	75
Gallatin	750,000	75
Jefferson	88,000	75
Deerlodge	666,000	68
Madison	527,000	60
Absaroka	819,000	60
Beartooth	203,000	41
Helena	440,000	40
Lewis and Clark	750,000	30
Forests in which lodgepole pine is of commercial but not of primary importance:		
Bitterroot	1,713,000	46
Blackfeet	225,000	10
Flathead	819,000	13
Lolo	118,000	7
Kootenai	600,000	5
Total	11,314,000	.....
WYOMING.		
Forests in which lodgepole pine is most important species:		
Medicine Bow	2,392,000	92
Washakie	255,000	85
Bighorn	895,000	80
Hayden	480,000	80
Bridger	432,000	70
Bonneville	426,000	60
Wyoming	408,000	40
Shoshone	396,000	24
Total	5,684,000	.....
COLORADO.		
Forests in which lodgepole pine is most important species:		
Arapaho	1,517,000	65
Colorado	753,000	61
Forests in which lodgepole pine is of commercial but not of primary importance:		
Holy Cross	260,000	40
Leadville	385,000	34
Routt	417,000	25
Gunnison	88,000	18
Sopris	73,000	10
Pike	86,000	8
White River	55,000	5
Cochetopa	12,000	3
San Isabel	17,000	2
Total	3,663,000	.....
IDAHO.		
Forests in which lodgepole pine is most important species:		
Idaho	2,210,000	85
Targhee	420,000	50
Palisade	112,000	32
IDAHO—continued.		
Forests in which lodgepole pine is of commercial but not of primary importance:		
Challis	370,000	37
Caribou	24,000	35
Nez Perce	875,000	25
Selway	1,818,000	25
Minidoka	58,000	20
Sawtooth	146,000	20
Boise	371,000	11
Weiser	146,000	11
Salmon	100,000	5
Payette	153,000	3
Clearwater	120,000	2
Coeur d'Alene	10,000	0.3
Total	6,933,000	.....
UTAH.		
Forests in which lodgepole pine is most important species:		
Ashley	1,446,000	65
Uinta	732,000	60
Forest in which lodgepole pine is of commercial but not of primary importance:		
Cache	6,000	5
Total	2,184,000	.....
WASHINGTON.		
Forests in which lodgepole pine is of commercial but not of primary importance:		
Wenaha	2,080,000	40
Okanogan	900,000	15
Chelan	277,000	12
Kaniksu	67,000	5
Wenatchee	41,000	1
Total	3,365,000	.....
OREGON.		
Forests in which lodgepole pine is of commercial but not of primary importance:		
Paulina	2,456,000	50
Minam	799,000	33
Deschutes	798,000	19
Whitman	440,000	10
Wallowa	251,000	6
Umatilla	45,000	3
Fremont	132,000	2
Malheur	105,000	1.6
Ochoco	118,000	1.3
Total	5,144,000	.....
CALIFORNIA.		
Forests in which lodgepole pine is of commercial but not of primary importance:		
Lassen	1,200,000	10
Sequoia	469,000	7
Kern	309,000	5
Mono	105,000	30
Total	2,083,000	.....

Total stand of lodgepole pine on those National Forests where it is of commercial importance, 40,380,000,000 board feet.

CHARACTERISTICS OF THE WOOD.

The wood of lodgepole pine is straight grained, with narrow rings in which the resinous bands of summerwood are conspicuous, though relatively small when compared with the springwood. It is more resinous than eastern white pine (*Pinus strobus*), but less so than the yellow pines of the South and West. In color it varies from almost white to a light yellow or yellow-brown, with a tinge of red in the heartwood. Its specific gravity (oven dry) is about 0.38, and its weight varies from 25 to 30 pounds per cubic foot. The wood is fairly soft—about the same as eastern white spruce (*Picea canadensis*)—and is easily worked. Though not so strong as Douglas fir of the Pacific coast (*Pseudotsuga taxifolia*), a heavier wood, tests made by the Forest Service show it to be practically as strong as western yellow pine (*Pinus ponderosa*), and stronger than Engelmann spruce (*Picea engelmanni*) and Alpine fir (*Abies lasiocarpa*), three woods of more nearly its weight. Tests made on lodgepole pine and western red cedar (*Thuja plicata*) telephone poles cut green and seasoned showed lodgepole pine to be the stronger, both in crossbending and in compression parallel and perpendicular to the grain. The strength of fire-killed lodgepole-pine poles was found to be approximately the same as that of red cedar poles cut green and seasoned. Lodgepole pine is not durable in contact with the soil, but is easy to treat with preservatives. Plate I shows magnified sections of the wood. Table 2 gives figures of strength for green and air-seasoned lodgepole pine compared with figures for other Rocky Mountain woods.

TABLE 2.—*Strength of green*[1] *and air-seasoned*[1] *lodgepole-pine timber, compared with other Rocky Mountain species.*

[Based on tests of small, clear specimens, 2 by 2 inches in cross section, with a 28-inch span in the bending test.]

Species and locality.	Rings per inch.	Specific gravity.[1]	Moisture content.	Static bending.			Compression parallel to grain (crushing strength).	Compression perpendicular to grain (fiber stress at elastic limit).
				Modulus of rupture.	Modulus of elasticity.	Work to maximum load.		
			Per cent.	*Lbs. per sq. in.*	*1,000 lbs. per sq. in.*	*Inch-lbs. per cu. in.*	*Lbs. per sq. in.*	*Lbs. per sq. in.*
Lodgepole pine, Grand County, Colo.	21	0.370	44	5,130	1,015	5.1	2,530	364
		.392	11.0	8,740	1,270	6.7	5,520	779
Lodgepole pine, Johnson County, Wyo.	30	.371	58	5,170	972	5.3	2,400	332
		.390	12.0	8,750	1,176	5.2	5,330	824
Douglas fir, Johnson County, Wyo.	17	.418	32	6,340	1,242	7.0	2,920	427
		.435	12.0	9,320	1,392	6.3	6,050	744
Western yellow pine, Coconino County, Ariz.	21	.353	98	4,760	879	4.9	2,220	342
		.384	11.6	8,150	1,103	4.6	5,220	790
Western yellow pine, Douglas County, Colo.	32	.391	93	5,460	1,053	6.0	2,600	410
		.411	13.8	9,400	1,263	7.0	4,920	714
Western yellow pine, Missoula County, Mont.	18	.371	119	4,950	865	5.2	2,370	313
Engelmann spruce, Grand County, Colo.	17	.325	45	4,550	866	4.8	2,170	302
		.342	12.8	7,740	1,074	5.4	4,560	589
Engelmann spruce, San Miguel County, Colo.	11	.299	156	3,850	798	5.0	1,800	279
		.314	16.8	5,860	990	5.4	3,060	447
Alpine fir, Grand County, Colo.	15	.306	47	4,450	861	4.4	2,060	307
		.321	15.9	5,960	887	3.4	3,400	504

[1] Based on oven-dry weight and volume when tested for strength.

NOTE.—Values for green timber on first line, for air-dry on second line, opposite species and locality.

USES.

MINE TIMBERS AND CONVERTER POLES.

In Montana lodgepole pine is used mainly for mine timbers. Butte offers the greatest single market for the wood to be found anywhere, consuming annually about 250,000 lodgepole-pine stulls, scaling some 10,000,000 board feet, and 130,000 lagging poles. The stulls vary in length from 14 to 16 feet, and in diameter from 6 to 23 inches. The lagging poles are 16 feet long, with a diameter of only 3 or 4 inches.

Butte consumes annually about 95,000,000 board feet of timber of all kinds, of which nearly 90 per cent is sawed yellow pine, fir, and larch (*Larix occidentalis*), the remainder being made up largely of the round lodgepole-pine timbers mentioned in the preceding paragraph. Wherever practicable mine operators are now replacing the sawed timber with lodgepole-pine timber in the round for the sake of economy. Sawed timber at Butte costs approximately $18 per thousand board feet, while an equivalent amount of lodgepole pine, from the standpoint of strength, can be delivered there for $8.50. Round lodgepole-pine timber, moreover, is "framed" by machinery, while the sawed timber must usually be framed by hand, a more expensive process.

In addition to the metal mines, the coal mines of Montana, Wyoming, and Colorado consume large quantities of lodgepole pine in the round, and this market is steadily growing. Still another market is offered by the smelters at Anaconda and Great Falls, which use annually about 50,000 converter poles, from 24 to 30 feet long and from 3 to 5 inches in diameter, in the final process of deoxidizing the matte.

RAILWAY TIES.

Lodgepole pine has been used for crossties ever since the first transcontinental railroad was built across the Rocky Mountains. Its short life in service under natural conditions, however, does not recommend it to the railroads as a tie material unless it can be treated with preservatives. At present lodgepole pine is not much used for ties in Montana, because the treating plants maintained by the Great Northern and Northern Pacific Railroads are both located in the western part of the State, where large quantities of Douglas fir and larch are available. As the supply of these woods is reduced, however, it is likely that lodgepole pine will find a much wider use in Montana as a tie material.

In Wyoming lodgepole pine is used in considerable quantities for crossties, two of the transcontinental railroads maintaining large treating plants at Laramie and Sheridan, respectively, at the first

of which lodgepole pine is the only wood treated and at the other forms the bulk of the material handled. Both plants use zinc chloride as the preservative, injecting a solution into the timber under pressure. Census figures show that in 1911 92,158 ties were treated by this process in Wyoming. One of the railroads estimates the life of a treated lodgepole-pine tie at 10 years, as compared with 5 years when untreated.

The wood is not used for ties to any extent in Colorado, and the material employed is untreated.

LUMBER.

Lodgepole pine finds a relatively small use as lumber, forming only 0.1 per cent of the total lumber cut of the United States. Even in mature stands only about 20 per cent of the material is large enough for saw timber, and the logs taken out run from 20 to 30 to the thousand board feet. Such sizes do not yield wide lumber, and are more expensive to log than larger stuff. The mills in the lodgepole region, moreover, are as a rule not equipped to turn out a high-grade product. Yet, when carefully manufactured, lodgepole pine lumber is by no means as inferior as many persons seem to believe. In quality it ranks between western yellow pine and western white pine (*Pinus monticola*), and in fact, is usually mixed with the former, and sometimes with the latter. While the small sound knots which are characteristic of lodgepole pine make it difficult to turn out any large quantity of clear lumber, they do not prevent a high percentage from going into No. 1 and No. 2 common of the narrower widths. At present most of the lodgepole pine lumber is used locally for rough construction and repairs, though in some places where other species are not available it is also used for flooring, siding, and finish.

Table 3, which is based upon figures gathered by the census, shows that the use of lodgepole pine for lumber, though restricted, is steadily increasing. As a matter of fact, the annual increase in the lumber cut is probably even greater than the table indicates, since the figures for 1909 are based on reports from a larger number of mills, and so more nearly represent the total cut for the year than those for 1910 and 1911. It is also probable that the cut of lodgepole pine in the "Inland Empire" (northwestern Montana, northern Idaho, and eastern Washington) is larger than that shown, due to the fact that many mills in the region market lodgepole pine with lumber of other species under the name of the latter, and report it as such.

TABLE 3.—*Annual cut of lodgepole pine for lumber, 1909–1911.*

State.	1909	1910		1911	
	Annual cut.	Annual cut.	Increase over previous year.	Annual cut.	Increase over previous year.
	Board feet.	*Board feet.*	*Per cent.*	*Board feet.*	*Per cent.*
Wyoming	11,886,000	13,205,000	11.1	13,294,000	0.7
Colorado	6,730,000	9,572,000	43.7	15,038,000	57.1
Montana	2,567,000	2,308,000	[1] 7.3	3,348,000	40.7
Idaho	1,228,000	934,000	[1] 23.9	779,000	[1] 14.5
All other States	1,322,000	543,000	[1] 58.9	535,000	[1] 1.5
Total	23,733,000	26,634,000	12.2	33,014,000	24.0

[1] Decrease.

POSTS AND POLES.

Large quantities of lodgepole pine are cut for fence posts and rails for local use, but at present the species is not generally employed for telegraph, telephone, or power line poles. Lodgepole pine, however, is in many respects an excellent pole timber. It is straight, with a taper of approximately 1 inch in 8 feet, about the same as that of western red cedar, and when air dried is 19 per cent stronger at the elastic limit and 12 per cent stronger under maximum load than a cedar pole of the same circumference at the ground line. The poles must, of course, be given a preservative treatment if they are to last any length of time. Poles treated with creosote by the open-tank process are estimated to have a life of 20 years or more, against 5 years when untreated. Even treated lodgepole, however, would be a cheaper pole material than untreated western red cedar in central and eastern Montana and in many portions of the region between the Rocky Mountains and the Mississippi River, owing to its lower stumpage value and greater accessibility. Table 4 shows the cost of treated lodgepole pine, in contrast with that of untreated cedar, for a telephone line near Butte.

TABLE 4.—*Comparative cost of treated lodgepole pine and untreated western red cedar telephone poles near Butte, Mont.*

	Treated lodgepole.[1]	Untreated cedar.
Cost per 7-inch, 25-foot pole, f. o. b. Butte	$0.75	$2.25
Cost of treatment	.60	.....
Cost of hauling and setting	5.00	5.00
Total cost in place	6.33	7.25
Life in service	[2]22 yrs.	10 yrs.
Annual charge[3]	$0.527	$0.985
Annual saving per pole by using lodgepole pine	.458	.....

[1] Treated with 4 pounds of creosote per cubic foot; penetration of 1.29 inches.
[2] Estimated.
[3] Calculated by the formula—

$$r=\frac{R\times 1.0p^n\times .0p}{1.0p^n-1}$$

where r=equivalent annual charge; R=initial expenditure; $.0p$=rate of interest; n=term of years.

Two factors operate against lodgepole pine as a substitute for cedar poles. The first is its greater hardness, which makes climbing more difficult for the lineman; the second is its greater weight—approximately 30 per cent after 3 months' seasoning—which means a higher freight rate for poles of the same size. Lodgepole pine, however, grows much farther east than cedar, and so should really have the advantage in freight rate for a considerable distance into middle western markets. Treated lodgepole pine poles, furthermore, do not need to be as large in circumference at the ground as cedar poles, for the latter must be large enough in the first place to bear the load after the sapwood and part of the heartwood have decayed. For this reason the shipping weight of treated lodgepole pine poles should be close to that of cedar when the same strength is required.

From present indications it seems likely that lodgepole pine will to a large extent replace cedar as a pole material in many parts of the West within the next few years.

PAPER PULP.

Lodgepole pine yields a ground-wood pulp of good quality, suitable for the manufacture of news-print paper. It can also be made into pulp by the sulphite process.

The National Forests contain many large bodies of lodgepole pine timber conveniently located with reference to undeveloped water power. No doubt the manufacturer of news-print paper will stick to white spruce for his raw material as long as any can be obtained either in this country or in Canada, but the lodgepole pine of the National Forests offers an immediate opening to manufacturers of other ground-wood products who have not an abundance of raw material and cheap power at their present locations. The rapid growth of the pulp-board industry during the last few years, for example, has created a demand for a suitable and inexpensive wood which lodgepole could well supply.

FUEL AND CHARCOAL.

A considerable amount of lodgepole pine is used locally for fuel. At one time large quantities were made into charcoal, but the industry has fallen away since the introduction of coke. From 15,000 to 20,000 bushels are still produced annually, however, in the vicinity of Bernice, Mont.

FIRE-KILLED TIMBER.

Lodgepole-pine timber killed by either fire or insects deteriorates very slowly as long as it remains standing. Dead trees may stand for 20 or 30 years, and even after falling to the ground will not decay quickly unless in direct contact with the soil. Finally, however, the interior of the stem gives way to red rot, leaving the sapwood as a

hard shell on the outside. The principal damage to standing dead timber comes from checking, which impairs its value for saw purposes, but not for mine timbers and poles. In one stand of lodgepole pine on the Beartooth National Forest, Mont., where the timber was killed by fire in 1893, a sawmill is now at work cutting rough lumber for local use.

SIZE AND CONTENTS OF VARIOUS PRODUCTS.

Table 5 gives the sizes of the various lodgepole-pine products and the contents of the average pieces of each class in cubic feet and board feet. Material under 6 inches in diameter has been converted from cubic feet to board feet by using the factor 4.

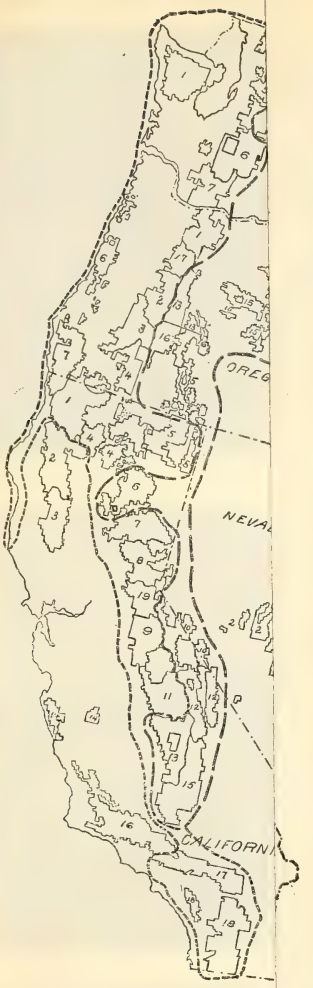
TABLE 5.—*Sizes and contents of various products of lodgepole pine.*

Product.	Dimensions.	Cubic feet equivalent.[1]	Board feet equivalent.	Number of pieces per 1,000 board feet.
Fuel	4′ x 4′ x 8′	82.42	330	3
Ties (pole ties)	7″ to 8″, 8″ to 10″ face, 8′ long[2]	6	30	33
Telephone poles	5″ to 6″ x 22″[3]	5.9	24	42
Derrick poles	7″ x 30′	15	60	17
Converter poles	3″ to 4″ x 24′	3	12	83
Fence poles	2½″ x 16′	1	4	250
Fence posts, round	5″ to 6″ x 7′	1.4	6	167
Fence stays	2″ x 6′	.21	.5	2,000
Do	4″ x 6′	.67	2	500
Lagging, round	2½″ x 16′	1	4	250
Mine props	5″ x 14′	2.7	11	91
Round material, cubic feet, average log	6″ to 16′	4.3	20	50
Do	8″ to 16′	7.1	30	33
Do	16″ to 16′	25.2	160	6
Round material, linear feet	6″ x 1′			
Do	8″ x 1′			
Do	10″ x 1′	.545	2.5	400
Do	12″ x 1′	.785	3.5	286

[1] Cubic foot equivalent is taken from Table I, Graves's Forest Mensuration, p. 107.

[2] These are Union Pacific specifications, but they are not always rigidly enforced. Ties fulfilling specifications would scale about 37 board feet each. Actual scale of ties in several places shows average contents to vary from 22.5 to 37 board feet. An average of 30 board feet per tie for the region is reasonable.

[3] This size used locally by ranchers.



IDAHO:
1. Boise.
2. Pend Oreille.
3. Coeur d'Alene.
4. Clearwater.
5. Nezperce.
6. Idaho.
7. Wieser.
8. Payette.
9. Kaniksu.
10. Minidoka.
11. Pocatello.
12. Cache.
13. Caribou.
14. Palisade.
15. Salmon.
16. Lemhi.
17. Challis.
18. Sawtooth.
19. St. Joe.
20. Selway.
21. Targhee.

MONTANA:
1. Kootenai.
2. Sioux.
3. Lewis and Clark.
4. Flathead.
5. Cabinet.
6. Lolo.
7. Bitterroot.
8. Missoula.
9. Deerlodge.
10. Beaverhead.
11. Madison.
12. Gallatin.
13. Helena.
14. Jefferson.
15. Absaroka.
16. Beartooth.
17. Custer.
18. Blackfeet.

ARKANSAS:
1. Ozark.
2. Arkansas.

KANSAS:
1. Kansas.

WYOMING:
1. Sundance.
2. Shoshone.
3. Bridger.
4. Teton.
6. Wyoming.
7. Bighorn.
8. Medicine Bow.
9. Hayden.
10. Bonneville.
11. Washakie.
14. Palisade.
21. Targhee.

ARIZONA:
1. Dixie.
2. Kaibab.
3. Coconino.
4. Sitgreaves.
5. Apache.
6. Crook.
7. Tonto.
8. Chiricahua.
9. Coronado.
10. Tusayan.
11. Prescott.
12. Zuni.

UTAH:
1. La Sal.
2. Ashley.
3. Uinta.
4. Wasatch.
5. Nebo.
6. Manti.
7. Fishlake.
8. Powell.
9. Sevier.
10. Fillmore.
11. Dixie.
12. Cache.
13. Minidoka.

NEVADA:
1. Humboldt.
2. Toiyabe.
3. Nevada.
4. Moapa.
5. Santa Rosa.

SOUTH DAKOTA:
1. Black Hills.
2. Sioux.
3. Harney.

MINNESOTA:
1. Superior.
2. Minnesota.

NEBRASKA:
1. Nebraska.

COLORADO:
1. La Sal.
2. Colorado.
3. Arapaho.
4. White River.
5. Holy Cross.
6. Leadville.
7. San Isabel.
8. Rio Grande.
9. San Juan.
10. Montezuma.
11. Uncompahgre.
12. Gunnison.
13. Sopris.
14. Battlement.
15. Routt.
16. Pike.
17. Cochetopa.
18. Durango.

NEW MEXICO:
1. Jemez.
2. Zuni.
3. Carson.
4. Pecos.
5. Manzano.
6. Lincoln.
7. Alamo.
8. Chiricahua.
9. Datil.
10. Gila.

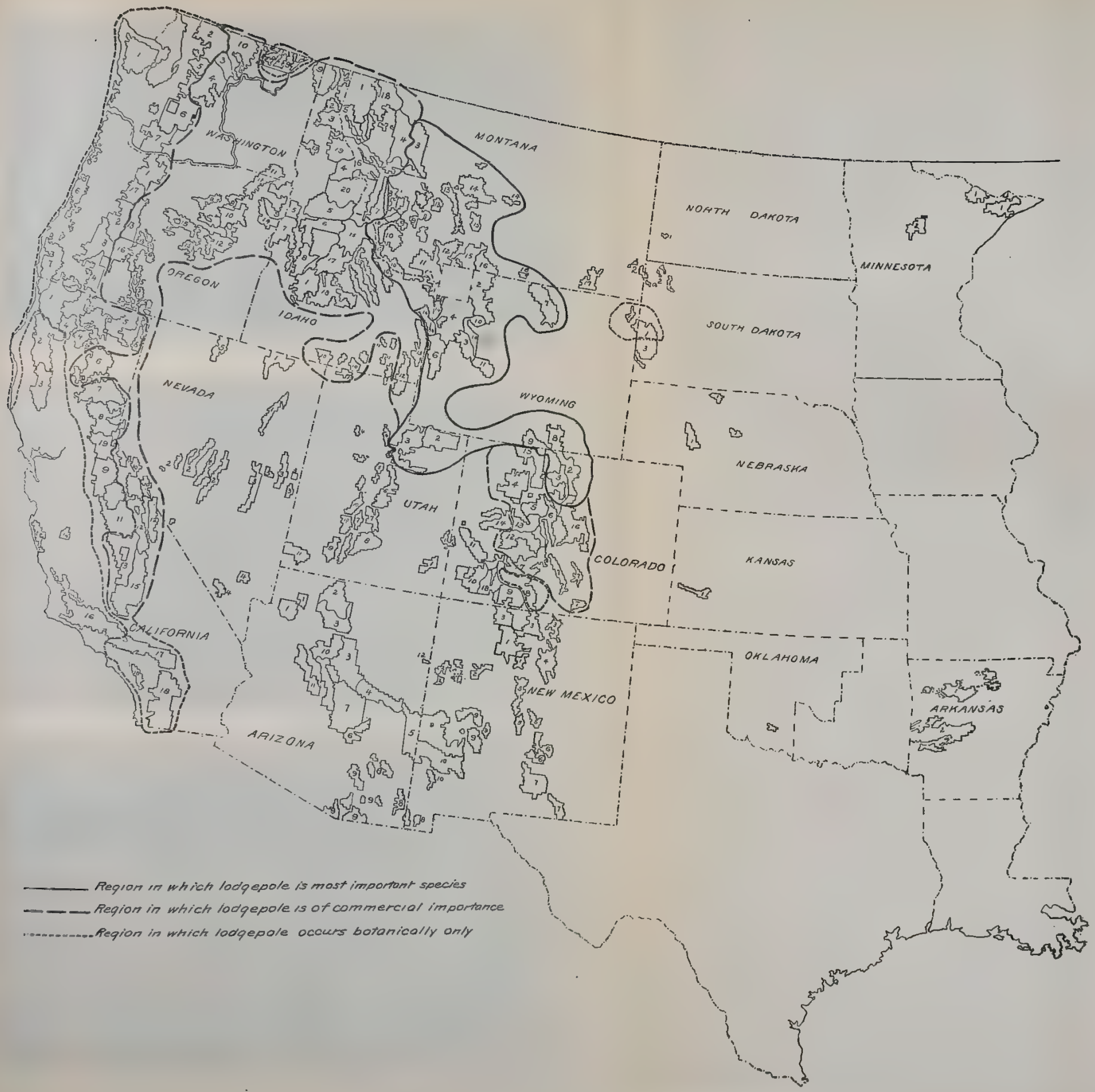
CALIFORNIA:
1. Klamath.
2. Trinity.
3. California.
4. Shasta.
5. Modoc.
6. Lassen.
7. Plumas.
8. Tahoe.
9. Stanislaus.
10. Mono.
11. Sierra.
12. Inyo.
13. Sequoia.
14. Monterey.
15. Kern.
16. Santa Barbara.
17. Angeles.
18. Cleveland.
19. Eldorado.

NORTH DAKOTA:
1. Dakota.

OKLAHOMA:
1. Wichita.

OREGON:
1. Oregon.
2. Cascade.
3. Umpqua.
4. Crater.
5. Fremont.
6. Siuslaw.
7. Siskiyou.
8. Umatilla.
9. Wallowa.
10. Whitman.
11. Wenaha.
12. Malheur.
13. Deschutes.
14. Minam.
15. Ochoco.
16. Paulina.
17. Santiam.

WASHINGTON:
1. Olympic.
2. Washington.
3. Chelan.
4. Wenatchee.
5. Snoqualmie.
6. Rainier.
7. Columbia.
8. Colville.
9. Kaniksu.
10. Okanogan.
11. Wenaha.



IDAHO:
1. Boise.
2. Pend Oreille.
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15. Salmon.
16. Lemhi.
17. Challis.
18. Sawtooth.
19. St. Joe.
20. Selway.
21. Targhee.

MONTANA:
1. Kootenai.
2. Sioux.
3. Lewis and Clark.
4. Flathead.
5. Cabinet.
6. Lolo.
7. Bitterroot.
8. Missoula.
9. Deerlodge.
10. Beaverhead.
11. Madison.
12. Gallatin.
13. Helena.
14. Jefferson.
15. Absaroka.
16. Beartooth.
17. Custer.
18. Blackfeet.

ARKANSAS:
1. Ozark.
2. Arkansas.

KANSAS:
1. Kansas.

WYOMING:
1. Sundance.
2. Shoshone.
3. Bridger.
4. Teton.
6. Wyoming.
7. Bighorn.
8. Medicine Bow.
9. Hayden.
10. Bonneville.
11. Washakie.
14. Palisade.
21. Targhee.

ARIZONA:
1. Dixie.
2. Kaibab.
3. Coconino.
4. Sitgreaves.
5. Apache.
6. Crook.
7. Tonto.
8. Chiricahua.
9. Coronado.
10. Tusayan.
11. Prescott.
12. Zuni.

UTAH:
1. La Sal.
2. Ashley.
3. Uinta.
4. Wasatch.
5. Nebo.
6. Manti.
7. Fishlake.
8. Powell.
9. Sevier.
10. Fillmore.
11. Dixie.
12. Cache.
13. Minidoka.

NEVADA:
1. Humboldt.
2. Toiyabe.
3. Nevada.
4. Moapa.
5. Santa Rosa.

SOUTH DAKOTA:
1. Black Hills.
2. Sioux.
3. Harney.

MINNESOTA:
1. Superior.
2. Minnesota.

NEBRASKA:
1. Nebraska.

COLORADO:
1. La Sal.
2. Colorado.
3. Arapaho.
4. White River.
5. Holy Cross.
6. Leadville.
7. San Isabel.
8. Rio Grande.
9. San Juan.
10. Montezuma.
11. Uncompahgre.
12. Gunnison.
13. Sopris.
14. Battlement.
15. Routt.
16. Pike.
17. Cochetopa.
18. Durango.

NEW MEXICO:
1. Jemez.
2. Zuni.
3. Carson.
4. Pecos.
5. Manzano.
6. Lincoln.
7. Alamo.
8. Chiricahua.
9. Datil.
10. Gila.

CALIFORNIA:
1. Klamath.
2. Trinity.
3. California.
4. Shasta.
5. Modoc.
6. Lassen.
7. Plumas.
8. Tahoe.
9. Stanislaus.
10. Mono.
11. Sierra.
12. Inyo.
13. Sequoia.
14. Monterey.
15. Kern.
16. Santa Barbara.
17. Angeles.
18. Cleveland.
19. Eldorado.

NORTH DAKOTA:
1. Dakota.

OKLAHOMA:
1. Wichita.

OREGON:
1. Oregon.
2. Cascade.
3. Umpqua.
4. Crater.
5. Fremont.
6. Siuslaw.
7. Siskiyou.
8. Umatilla.
9. Wallowa.
10. Whitman.
11. Wenaha.
12. Malheur.
13. Deschutes.
14. Minam.
15. Ochoco.
16. Paulina.
17. Santiam.

WASHINGTON:
1. Olympic.
2. Washington.
3. Chelan.
4. Wenatchee.
5. Snoqualmie.
6. Rainier.
7. Columbia.
8. Colville.
9. Kaniksu.
10. Okanogan.
11. Wenaha.

FIG. 1—Occurrence of Lodgepole pine in National Forests.

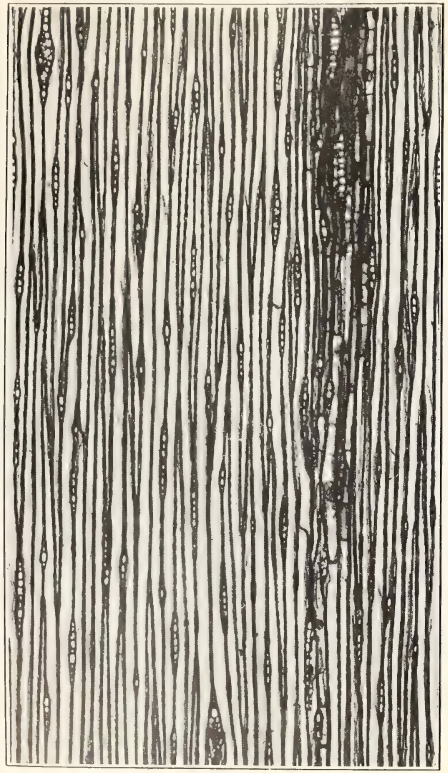

FIG. 1.—TANGENTIAL SECTION.

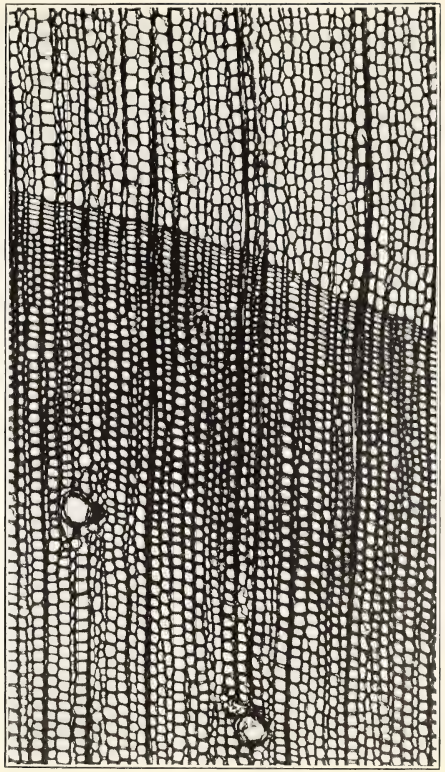

FIG. 2.—TRANSVERSE SECTION.

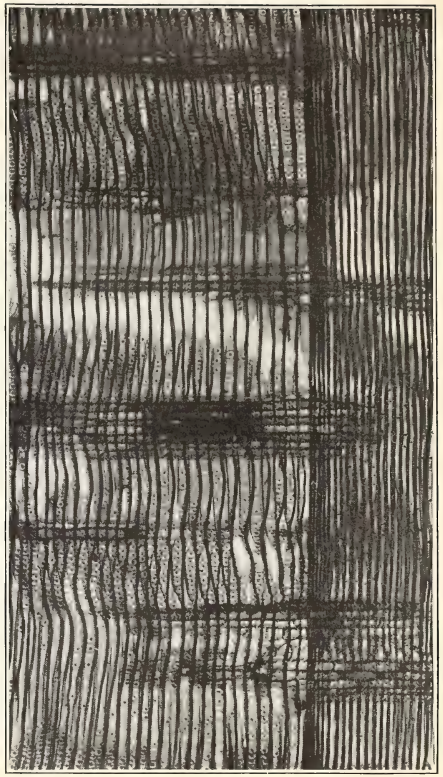

FIG. 3.—RADIAL SECTION.

LODGEPOLE-PINE WOOD MAGNIFIED 50 DIAMETERS.

FIG. 1.—CHUTE DOWN WHICH LODGEPOLE-PINE STULLS AND OTHER MATERIAL ARE BROUGHT TO RESERVOIR IN FOREGROUND, DEERLODGE NATIONAL FOREST.

FIG. 2.—FLUME FOR TRANSPORTING LODGEPOLE-PINE TIES, PROPS, AND SLABBED LOGS, BIGHORN NATIONAL FOREST.

Table 6 shows the contents in cubic feet and board feet of stulls of various sizes.

TABLE 6.—*Contents of stulls of various sizes, Deerlodge National Forest, Mont.*

Size.		Contents.		Number of pieces per thousand board feet.	Number of board feet per cubic foot.	Weight per piece (20 per cent moist 33.1 lbs. per cubic foot).[2]
Length.	Top diameter inside of bark.					
Feet.	*Inches.*	*Cu. ft.*	*Bd. ft.*[1]			*Pounds.*
14	5	2.7	5	200	1.8	89
	6	3.6	10	100	2.8	119
	7	4.5	20	50	4.4	149
	8	6.0	20	50	3.3	199
	9	7.6	30	33	4.0	252
	10	9.4	40	25	4.3	311
	11	11.4	50	20	4.4	377
	12	13.4	70	14	5.2	444
	13	15.6	80	12	5.1	516
	14	17.9	100	10	5.6	592
	15	20.3	120	8	5.9	665
	16	22.8	140	7	6.1	755
	17	25.7	160	6	6.2	851
	18	28.6	190	5	6.6	946
16	6	4.4	20	50	4.5	145
	7	5.8	30	33	5.2	192
	8	7.4	30	33	4.1	245
	9	9.2	40	25	4.3	304
	10	11.3	60	17	5.3	374
	11	13.5	70	14	5.2	447
	12	15.9	80	12	5.0	526
	13	18.3	100	10	5.5	606
	14	20.9	110	9	5.5	692
	15	23.6	140	7	5.9	781
	16	26.6	160	6	6.0	880
	17	29.9	180	5	6.0	990
	18	33.6	210	5	6.3	1,112

[1] Rounded off to even tens by the Scribner Decimal C rule.

[2] This is calculated for a uniform moisture content of 20 per cent, with a weight of 33.1 pounds per cubic foot. As a matter of fact, the moisture content at the time of shipment varies considerably—from 15 per cent to 60 per cent.

ANNUAL CUT.

The annual cut of lodgepole pine by States, as nearly as it can be determined, is shown in Table 7. This table indicates a considerably smaller cut of saw timber than Table 3, due to the fact that some mills which formerly sawed lodgepole pine have shut down, and to the further fact that some of the material included in Table 3 as saw timber appears in Table 7 as ties and mine timbers.

TABLE 7.—*Approximate total cut of lodgepole pine by States for year ending June 30, 1913.*

[The figures include the cut from private as well as from National Forest lands.]

State.	Total cut of lodgepole pine.	Mine timbers.	Saw timber.	Cordwood.	Railroad ties.	Fencing.	Miscellaneous.
	1,000 bd. ft.	*1,000 bd. ft.*	*1,000 bd. ft.*	*1,000 bd. ft.*	*1,000 bd. ft.*	*1,000 bd. ft.*	*1,000 bd. ft.*
Montana	30,497	14,632	2,805	8,554	108	4,083	315
Colorado	15,680	4,737	5,881	387	4,483	125	67
Wyoming	14,523	3,236	7,646	1,246	1,622	697	76
Utah	10,753	1,955	1,808	90	6,842	58	.....
Idaho	6,880	167	1,273	2,624	494	1,349	973
Oregon	1,916	43	64	1,048	222	498	41
Washington	1,765	.....	.....	1,582	.....	182	1
California	236	.....	86	120	.....	.....	30
Total	82,250	24,770	19,563	15,651	13,771	6,992	1,503
Total cut from private lands	18,725	3,804	4,815	304	9,662	115	25
Per cent from private lands	22.8	15.4	24.6	1.9	70.2	1.6	1.7

METHODS OF LUMBERING.

Lodgepole-pine stands are logged with horses, steam logging being impracticable because of the small size of the timber and the small stand per acre. The ordinary lumbering operation may be divided into four parts: (1) Felling the trees and cutting them into logs, ties, mine timbers, and other products; (2) skidding the material to hauling roads and hauling on wagons or sleds to a flume, river, chute, or railroad, and, in some cases, direct to the mill; (3) fluming, driving, or railroading the material to the mill or market; and (4) milling. Cutting and skidding are done mainly in the summer and fall and driving and fluming in the spring. Railroad hauling may of course be carried on at any season. The exact methods adopted for each part of the lumbering operation differ with local conditions and the class of material handled.

FELLING AND CUTTING.

Saw logs are cut in the usual manner by a two-man crew that fells the tree, trims the branches, and cuts the stem into log lengths. In average timber such a crew will cut from 4,500 to 5,000 board feet, log scale, per day.

Tie trees—that is, trees from 11 to 15 inches in diameter, breast-high—are felled and hewed into ties by one man, who uses a single crosscut saw for felling and a broadax for hewing. The trees are marked into 8-foot lengths and hewed along two parallel faces to the proper dimensions. The bark is then peeled from the upper side, and the portion of the tree suitable for ties is cut up into the proper lengths. If the tree is a large one the tie cutter ordinarily cuts one saw log from the butt, while the top portion is left in the round and utilized for mine timbers. On the basis of figures for 15 trees, averaging 12.1

inches in diameter, with three ties to a tree, a tie maker produces about 21.5 ties in 8 hours' work with a distribution of time per tie as follows:

	Time per tie.	Per cent of total.		Time per tie.	Per cent of total.
	Minutes.			*Minutes.*	
Felling	1.6	7.2	Time lost between trees	1.2	5.4
Trimming and making	1.1	4.9	Sharpening tools	1.2	5.4
Scoring	3.4	15.2	Strip road building	1.0	4.5
Hewing	4.2	18.8	Parking ties	2.5	11.7
Peeling (top side)	1.2	5.4			
Sawing	2.6	11.7	Total	22.3	100
Peeling (underside)	2.2	9.8			

Often he cuts the saw-log trees, or at least the smaller ones, as well as the tie trees. In tie operations it is the usual practice to lay out the timber in parallel strips from 100 to 150 feet wide, each of which is assigned to a tie cutter. A road is then cut through the middle of each strip or, if the topography does not permit this, between every two strips. The choppers usually dispose of the brush, although this may be done by a separate crew.

In a typical tie operation on the Uinta National Forest, in Utah, the specifications provided for ties 8 feet long, from 7 to 8 inches thick, with from 8 to 10 inches face. Seven-inch faces were allowed in not to exceed 20 per cent of the first-class ties. Cull ties were required to have a minimum face of 6 inches, but had to meet the other specifications as to length and thickness. The stand in which the cutting was done averaged slightly less than 12,000 board feet per acre, with 72 per cent suitable for hewed ties, 18.5 per cent for saw logs, and 9.5 per cent for mine timbers. From 126 to 460 ties, or an average of 228, were secured per acre. The "tie hacks" were required to construct the roads through the middle of the 100-foot strips and also to park the ties along these roads, but were not required to dispose of the brush. They were paid 14 cents for first-class and 7 cents for cull ties, but were not paid for rejects. At the final inspection the product of the cutting was shown to be 97 per cent first-class ties, 2.5 per cent culls, and 0.5 per cent rejects. Thus the average price paid to the cutters per tie amounted to 13.7 cents. The cutters received $1.50 per thousand board feet for saw logs over 13 inches in diameter, though ordinarily the portion of the tree over 13 inches was made into ties like the rest. The ties, which were unusually large, showed an average scale of 37 board feet each, or 27 pieces to the thousand board feet. At a treating plant at Laramie, Wyo., 150 ties gave an average scale of 28.2 board feet each, or 35.5 pieces per thousand board feet. Some 2,000 ties scaled on the Bighorn National Forest, in Wyoming, averaged 26 board feet per tie, and an equal number on the Arapahoe Forest, Colo., averaged 22.5 board feet.

Where the cutting is mainly for mine timbers, as is the case in most parts of Montana, the various classes of material are produced in the woods by small groups of choppers at contract prices. Each group, usually called a "company," consists of from 2 to 5 men, and is assigned to a definite area of from 5 to 15 acres. The men of each group fell the trees, saw them into proper lengths, peel the bark from the stulls, and dispose of the brush. In Forest Service timber sales the latter must be burned. During the safe months of the year, from October 1 to June 1, the men burn the brush as the cutting proceeds, but in summer they pile it for burning in the fall. Stumps are cut low, usually from 4 to 12 inches high. In winter, holes from 4 to 6 feet deep often have to be shoveled out to reach the proper point for cutting the trees. Although it is difficult to work under such conditions, particularly since the days are short and are likely to be stormy, work usually goes on throughout the year. Based on data obtained in connection with a sale at French Gulch, on the Deerlodge National Forest, the cost per thousand board feet of producing stulls amounts to $4.56. This includes shoveling snow, felling and trimming the trees, disposing of the brush, cutting the timber into stull lengths, and peeling. Fifteen per cent of the total cost is chargeable to snow disposal, while the largest single item is peeling, which costs $1.55 per thousand board feet, or 34 per cent of the total. The complete distribution of time in stull making at French Gulch, Mont., was as follows:

Operation.	Time spent in producing 1,000 board feet.	Cost per 1,000 feet.	Per cent of total cost.
	Minutes.		
Shoveling snow	72	$0.68	15
Felling trees	50	.48	10
Trimming trees	20	.19	4
Brush disposal, piling and burning	77	.73	16
Cutting into stull lengths	100	.93	21
Peeling	165	1.55	34
Total	484	4.56	100

SKIDDING AND HAULING.

After the trees have been felled and cut into the proper lengths, the logs, ties, mine timbers, and other products are skidded with teams or single horses into skidways along the hauling roads or other line of transportation. Whatever brush cutting or removal of down timber is necessary to open the way for skidding it is done either by swampers or by the skidders themselves. Where logging is easy and the distance short, tie cutters often skid their own ties on a light hand-sled over the snow, hauling about 10 ties to the load. Ties cut from trees near a stream which is to be driven or a main logging road are nearly always "hand-banked" in this manner. In Forest

Service timber sales the different classes of material are often scaled or counted by forest officers before being skidded. This scale is accepted by purchasers as a basis of settlement with the choppers.

In nearly all operations most of the hauling from the skidway to the flume, river, or railroad is done with sleighs on snow roads. The use of sleighs, which is possible from four to six months in the year, is by far the most economical and efficient method of hauling. Sometimes, however, where the haul is short and good roads are easily made, the material is carried on heavy trucks over the bare ground. This latter method is most common in small operations where a constant supply of logs and ties is required.

Chutes are sometimes used to get the products down steep grades to the main line of transportation.

TRANSPORTATION TO MILL.

In the smaller logging operations ties and mine timbers are usually hauled direct from the skidway to the railroad, shipping point, or market; the logs direct to the mill. In large operations, however, where the timber must be transported for from 20 to 100 miles or more, the method of transportation will depend upon the character of the area which is being logged. Ordinarily, the mountainous nature of the lodgepole region and the character of the timber prevent the use of logging railroads. Where the timber must be transported over a long distance it is a common practice to float it down some stream. Ties can be driven in streams which are too small to carry saw logs, which gives tie logging a decided advantage. Many small creeks have been made driveable for ties during the spring high water with only a little work in clearing the channel. In the larger streams of Wyoming and Colorado all classes of material have been driven for distances of 100 miles or more.

For shorter distances flumes have occasionally been used to good advantage, and in the future will undoubtedly play a more important part in the transportation of lodgepole pine. All the material from the French Gulch timber sale on the Deerlodge National Forest is removed by a flume about 18 miles long crossing the Continental Divide. The timber from above is hauled on sleds or trucks or is chuted down to the flume, where it is banked for fluming during the open season, which usually lasts from about May 1 to November 1. The timber from below is first banked along a tramway, up which the loaded cars are later hauled by a cable, operated by a stationary engine, to the banking grounds above the flume. A large proportion of this timber is delivered at the foot of the tram by means of secondary flumes located considerably below the main flume. The latter is V-shaped, with 24-inch sides. About 100,000 board feet of lumber per mile were used in its construction, and the original cost per mile was approximately $4,000. It has one tunnel 685 feet long, 29 tres-

tles over 25 feet high, the highest being 72 feet and the longest 775 feet, and 20 rock cuts from 8 to 20 feet deep. The minimum grade is one-half of 1 per cent and the maximum 12½ per cent. The sharpest curve is 20°. The flume carries from 200 to 800 inches of water, the supply of which is maintained by frequent feeders from small streams along its length. It can handle stulls up to 18 inches in diameter and poles up to 30 feet long, and has a capacity of about 1,800 stulls, 2,200 converter poles, 6,000 lagging poles, or 170 cords of wood in 10 hours. It is operated on the average for about 170 days each year. Operation costs, including rolling in, tending, and loading the material on cars at the dump, amount to $90 a day, to which must be added $70 a day for depreciation and maintenance. The secondary flumes have 18-inch sides, and the largest stull handled is 15 inches in diameter. They are more lightly built than the main flume, with about 33,000 board feet of lumber per mile, and cost about $1,500 per mile.

A similar V-shaped flume, 25 miles long, has been used for the last 7 years on the Bighorn National Forest for transporting ties, props, and logs from the woods to the mill and railroad. The larger logs are slabbed in a small sawmill at the head of the flume before being sent down.

MILLING.

Sawmill equipment used in lodgepole-pine operations does not differ from the usual type employed in the Rocky Mountains. Most of the lumber is cut by small mills, with a daily capacity of from 10,000 to 20,000 board feet, equipped with a single circular head saw, edger, trimmer, and sometimes a planer. In the few larger mills which cut lodgepole pine, band re-saws are used in conjunction with a circular head saw, and in addition, there is the usual equipment for making lath, flooring, siding, and other classes of finished lumber. In nearly all operations some sawed ties are turned out by the mill in addition to the hewed ties made in the woods.

COSTS AND SELLING PRICES.

The cost of producing lodgepole-pine lumber, ties, and props varies widely with topography, the character of the stand, and the size and efficiency of the operation. An idea of the probable expense incident to a lodgepole-pine operation can be best obtained from a statement of the average range of cost under various conditions, together with definite figures for a few specific operations. The range of cost for lumber, ties, and props in Wyoming and Colorado, under ordinary logging conditions and distances to market, is shown in Table 8. The cost of stumpage and such overhead charges as depreciation, taxes, insurance, and selling are not included, since these must be calculated for each individual case.

TABLE 8.—*Range in cost of production of lodgepole-pine saw timber, railroad ties, and mine props in Wyoming and Colorado.*

Operation.	Saw timber (log scale).	Railroad ties (standard gauge).	Mine props (all lengths).
	Per thousand board feet.	*Per tie.*	*Per linear foot.*
Felling, cutting, and trimming	$1.00–$1.50	$0.12–$0.16	$0.0020–$0.0050
Brush piling or lopping	.25– .50	.01– .02	.0005– .0010
Skidding	.75– 2.00	.01– .04	.0005– .0015
Hauling to flume, river, railroad, or main road [1]	1.00– 2.50	.02– .09	.0010– .0020
Fluming, driving, railroading, or hauling on main road	1.00– 3.00	.03– .10	.0010– .0080
Milling, piling, and delivering at market	4.00– 7.00		
Loading on cars at market point		.02– .03	.0010– .0020
Total cost at market [2]	8.00–16.50	.21– .44	.0060– .0195

[1] Includes building winter roads. [2] Without stumpage or overhead charges.

The figures which follow show the cost of an operation on private lands adjacent to the Arapaho National Forest, in Colorado, where 600,000 feet of logs were cut into rough boards and dimension material. Although in the actual operation no disposal was made of brush or débris, an item of 50 cents per thousand board feet has been included to make the cost comparable to similar operations on the National Forests, where brush piling is required. The stumpage price has been arbitrarily placed at $2 per thousand board feet.

	Per thousand board feet.
Felling and bucking into logs (cutting crew of 2 men, who also trim trees)	$1.21
Piling brush (done by separate crew of 1 or 2 men)	.50
Skidding (skidders do necessary swamping; maximum skid 500 feet; average 250 feet)	.77
Hauling logs to mill (haul on sleds; average distance 1¼ miles)	.84
Road building (roads for winter hauling only)	.13
Construction of logging camp	.13
Blacksmithing and repairing	.11
Supervision and accounting (includes wages of woods foreman)	.30
Decking at mill	.18
Depreciation of equipment (covers logging equipment only)	.02
Sawing (includes depreciation, taxes, and other charges on sawmill)	2.25
Yarding lumber at mill	.35
Hauling lumber to railroad (sled haul 4 miles to railroad)	1.00
Loading on cars	.50
Freight to market	2.75
Stumpage	2.00
Total cost at market	13.04
Selling price, mill run at market	15.00
Net profit (15 per cent on the operating cost) per thousand board feet	1.96

The following appraisal of conversion costs and stumpage prices for a block of pure lodgepole pine on one of the National Forests in Wyoming may be taken as typical of the larger operations. This sale would involve the cutting within a period of 5 years of approximately 45,000,000 board feet, of which about 33,000,000 feet is suitable for ties and the remainder for saw timber.

Estimated conversion costs and stumpage value of tie timber.

	Firsts.	Seconds.
Depreciation on improvements and equipment	$0.020	$0.0019
Maintenance of improvements and equipment	.018	.0020
Overhead expenses (office, supervision, sales, insurance, etc.)	.025	.0027
Current operating expenses:		
Making (felling, bucking, hewing)	.150	.100
Brush disposal and cutting defective timber	.030	.030
Hauling and banking	.060	.060
Driving and booming	.072	.072
Loading	.018	.018
Total cost of production	.393	.2866
Average cost (90 per cent first class; 10 per cent second class)	$0.3824	
Average price received, f. o. b. cars	.62	
Difference for profit and stumpage	.2376	
Stumpage value, allowing 20 per cent profit	.13	

Conversion costs and stumpage value of saw timber.

Logging:		Per thousand board feet log scale.
Depreciation on improvements and equipment		$0.51
Maintenance of improvements and equipment		.35
Overhead expenses (supervision, office, scaling, etc.)		.40
Current operating expenses—		
Felling and bucking	$1.00	
Swamping and skidding	1.10	
Brush disposal and defective timber	.75	
Temporary roads	.35	
Hauling and banking	1.45	
Driving and booming	1.12	
		5.77
Total cost of logs at mill		7.03

Milling and marketing:	Per thousand board feet. Lumber tally.	Log scale.[1]
Depreciation on improvements and equipment	$0.58	$0.70
Maintenance of improvements and equipment	.23	.28
Overhead expenses (sales, insurance, supervision, office, etc.)	.54	.65
Current operating expenses—		
Milling	2.18	2.62
Yarding	.54	.65
Planing and finishing	.83	1.00
Grading and loading	.55	.66
Total milling and marketing	5.45	6.56

[1] The amount of lumber actually sawed out at the mill is estimated to overrun that shown by the log scale by 20 per cent. Consequently the figures in this column are obtained by increasing by 20 per cent the costs per 1,000 board feet as shown by the lumber tally.

Summary:	Per thousand board feet log scale.
Logging	$7.03
Milling and marketing	6.56
Total cost, on cars	13.59
Average sale price per thousand board feet, mill run	15.80
Average sale price per 1,200 feet mill run [1]	18.96
Difference for profit and stumpage	5.37
Stumpage value, allowing 25 per cent profit	1.58

Table 9 gives in detail for a representative part of the French Gulch timber sale on the Deerlodge National Forest, Mont., the cost of production of various-sized stulls, converter poles, lagging poles, and cordwood. Table 10 shows the market price received for the various products, together with the net profit per piece or per cord. The figures per thousand board feet run high for the smaller pieces because of their extremely low board-foot contents.

TABLE 9.—*Itemized cost of production of lodgepole-pine stulls, converter poles, lagging poles, and cordwood; French Gulch timber sale, Deerlodge National Forest, Mont.*

Product.	Size.		Stumpage price.	Cutting, peeling, and brush disposal.[2]	Skidding 100 yards.[2]	Hauling 1 mile to flume.[2]	Fluming 15 miles and loading on cars.	Freight to market at 3 cents per 100 lbs.	Overhead charges, interest, etc.[3]	Total cost of production.
	Length.	Top diameter.								
	Feet.	*Inches.*								
Stulls	14	5	$0.02	$0.06	$0.05	$0.06	$0.05	.....	$0.01	$0.25
		6	.04	.08	.05	.06	.05	$0.03	.01	.32
		7	.08	.08	.05	.06	.06	.04	.03	.40
		8	.08	.16	.05	.10	.07	.06	.03	.55
		9	.12	.16	.05	.10	.08	.07	.05	.63
		10	.16	.16	.05	.10	.09	.09	.06	.71
		11	.20	.16	.05	.10	.10	.11	.07	.79
		12	.28	.16	.05	.10	.11	.13	.10	.93
		13	.32	.16	.05	.10	.12	.15	.12	1.02
		14	.40	.16	.05	.10	.13	.17	.15	1.16
		15	.48	.16	.05	.10	.14	.20	.19	1.32
		16	.56	.16	.05	.10	.15	.22	.21	1.45
		17	.64	.16	.05	.10	.16	.25	.25	1.61
		18	.76	.16	.05	.10	.17	.28	.30	1.82
	16	6	.08	.09	.05	.06	.06	.04	.03	.41
		7	.12	.10	.05	.06	.07	.06	.05	.51
		8	.12	.18	.05	.10	.08	.07	.05	.65
		9	.16	.18	.05	.10	.09	.09	.06	.73
		10	.24	.18	.05	.10	.10	.11	.08	.86
		11	.28	.18	.05	.10	.11	.13	.10	.95
		12	.32	.18	.05	.10	.12	.16	.12	1.05
		13	.40	.18	.05	.10	.13	.18	.15	1.19
		14	.44	.18	.05	.10	.14	.20	.17	1.28
		15	.56	.18	.05	.10	.15	.24	.21	1.49
		16	.64	.18	.05	.10	.16	.26	.25	1.64
		17	.72	.18	.05	.10	.17	.30	.30	1.82
		18	.84	.18	.05	.10	.18	.33	.30	1.98
Converter poles	24	3½	.10	.035	.05	.06	.08	.03	.03	.385
Lagging poles	16	2	.03	.0175	.01	.015	.02	.01	.012	.115
Cordwood		[4] 6	.50	1.25	.....	.75	.85	.90	.60	4.85

[1] Since the mill overrun is 20 per cent, 1,200 board feet mill run scale will equal 1,000 feet log scale. The mill run selling price of $15.80 per 1,000 board feet must, therefore, be increased by 20 per cent to make it comparable with the other figures, which are based on log scale.
[2] By contract.
[3] 8 per cent interest on $100,000 and $10,000 annual overhead charges.
[4] Average.

TABLE 10.—*Total cost of production, market price, and net profit for lodgepole-pine stulls, converter poles, lagging poles, and cordwood, Deerlodge National Forest, Mont.*

Product.	Size.		Per cent of entire cut by pieces.[1]	Cost of production per piece.[2]	Market price.[3]			Profit per piece.	Price at which square timber must sell per thousand board feet in Butte to equal round in price per cubic foot.
	Length.	Top diameter.			Per piece.	Per cubic foot.	Per 1,000 board feet.[4]		
	Feet.	*In.*							
Stulls	14	5	18.24	$0.25	$0.28	.....	.....	$0.03	.....
		6	16.76	.32	.36	$0.100	$36.00	.04	$8.33
		7	7.19	.40	.50	.111	25.00	.10	9.25
		8	4.30	.55	.71	.118	35.50	.16	9.84
		9	1.85	.63	.85	.112	28.33	.22	9.33
		10	.86	.71	1.00	.106	25.00	.29	8.84
		11	.39	.79	1.14	.100	22.80	.35	8.33
		12	.37	.93	1.41	.105	20.13	.48	8.75
		13	.12	1.02	1.55	.099	19.37	.53	8.25
		14	.07	1.16	1.72	.096	17.20	.56	8.00
		15	.04	1.32	1.90	.094	15.83	.58	7.73
		16	.02	1.45	2.07	.091	14.78	.62	7.58
		17	.01	1.61	2.25	.088	14.06	.64	7.33
		18	.005	1.82	2.46	.086	12.94	.64	7.16
	16	6	10.42	.41	.45	.102	22.50	.04	8.50
		7	11.12	.51	.59	.102	19.67	.06	8.50
		8	10.09	.65	.86	.116	28.67	.21	9.67
		9	7.18	.73	1.00	.109	25.00	.27	9.09
		10	4.74	.86	1.18	.104	19.67	.32	8.67
		11	2.76	.95	1.33	.099	19.00	.38	8.25
		12	1.69	1.05	1.45	.091	18.12	.40	7.58
		13	.89	1.19	1.63	.089	16.30	.44	7.42
		14	.43	1.28	1.76	.084	16.00	.48	7.00
		15	.22	1.49	1.98	.084	14.13	.49	7.00
		16	.12	1.64	2.15	.081	13.43	.51	6.75
		17	.06	1.82	2.33	.078	12.94	.51	6.50
		18	.05	1.98	2.54	.076	12.09	.56	6.35
Converter poles	24	3½	.....	.385	.385	.123	.....	.015	.....
Lagging poles	16	2	.....	.115	.12	.12	.....	.005	.....
Cordwood	.....	[5]6	.....	4.85	5.00	.063	.....	.15	.....

[1] Based on 262,621 pieces scaled in 1910–11.
[2] From Table 8.
[3] At the rocker stull framing plant, near Butte, for the stulls; at the Anaconda smelter for the converter poles; and at Butte for the lagging poles and cordwood, etc.
[4] Derived from the figures per piece by using the contents in board feet of pieces of different sizes given in Table 5.
[5] Average.

The stumpage price per piece shown in Table 9 is equivalent to one of $4 per thousand board feet. This price has been in effect for several years in the principal sales on the Deerlodge National Forest. When the prices for the various products were reduced to a cubic-foot basis, however, considerable irregularity was disclosed. Small-dimension material, for which the demand is relatively light, was bringing a higher price per cubic foot than the larger-dimension material, for which the demand is great and which takes longer and is more expensive to produce. Since the timber was not being sold for lumber nor actually scaled by the Decimal C rule, it was considered advisable to adopt a set of piece-rate prices, based on cubic-foot contents and increasing with the diameter and length of the

individual pieces. Table 11 shows the prices now in effect in lodgepole sales similar to those on the Deerlodge Forest. The Government obtains practically the same total return on all classes of material cut annually. The lower prices on smaller-sized material tend to encourage thinnings, while the higher prices for the larger timber offset the decreased returns from the former.

TABLE 11.—*Rate per cubic foot and price per piece for lodgepole-pine timber, Deerlodge National Forest, Mont.*

Top diameter.	Length, 10 feet.		Length, 12 feet.		Length, 14 feet.		Length, 16 feet.		Length, 18 feet.	
	Rate per cubic foot.	Price per piece.	Rate per cubic foot.	Price per piece.	Rate per cubic foot.	Price per piece.	Rate per cubic foot.	Price per piece.	Rate per cubic foot.	Price per piece.
Inches.	*Cents.*	*Cents.*	*Cents.*	*Cents.*	*Cents.*	*Cents.*	*Cents.*	*Cents.*	*Cents.*	*Cents.*
4	0.75	1	1.0	1.5	0.75	1.5	0.75	2	0.75	2
5	.8	1	1.0	2	.8	2.5	.8	3	.9	4
6	1.0	2	1.1	3	1.1	4.0	1.2	6	1.3	7
7	1.4	5	1.4	6	1.4	6.0	1.5	8	1.6	11
8	1.7	7	1.8	9	1.9	11.0	1.9	14	1.9	16
9	2.0	10	2.0	13	2.0	15.0	2.0	18	2.0	21
10	2.1	13	2.1	17	2.1	20.0	2.1	24	2.1	27
11	2.1	16	2.2	21	2.2	25.0	2.2	30	2.2	34
12	.....	.....	2.2	24	2.3	31.0	2.3	36	2.3	43
13	.....	.....	2.3	30	2.4	37.0	2.4	44	2.4	52
14	.....	.....	2.4	36	2.5	45.0	2.5	52	2.5	60
15	.....	.....	.....	.....	2.6	53.0	2.6	62	2.6	71
16	.....	.....	.....	.....	2.7	62.0	2.7	71	2.7	83
17	.....	.....	.....	.....	2.8	71.0	2.8	84	2.8	95
18	.....	.....	.....	.....	2.9	83.0	2.9	98	2.9	109

Top diameter.	Length, 20 feet.		Length, 25 feet.		Length, 30 feet.		Length, 35 feet.		Length, 40 feet.	
	Rate per cubic foot.	Price per piece.	Rate per cubic foot.	Price per piece.	Rate per cubic foot.	Price per piece.	Rate per cubic foot.	Price per piece.	Rate per cubic foot.	Price per piece.
Inches.	*Cents.*	*Cents.*	*Cents.*	*Cents.*	*Cents.*	*Cents.*	*Cents.*	*Cents.*	*Cents.*	*Cents.*
4	0.8	2.5	0.8	4	0.9	6	.....	.....	.....	.....
5	1.0	5	1.0	6	1.2	10	.....	.....	.....	.....
6	1.3	8	1.4	11	1.5	16	1.7	23	1.8	31
7	1.6	13	1.7	18	1.9	26	1.9	32	2.0	44
8	1.9	19	2.0	26	2.0	35	2.0	44	2.1	57
9	2.0	24	2.1	34	2.1	45	2.1	55	2.2	73
10	2.1	31	2.2	41	.....	.....	.....	.....	.....	.....
11	2.2	39	2.3	54	.....	.....	.....	.....	.....	.....
12	2.3	49	2.4	64	.....	.....	.....	.....	.....	.....
13	2.4	59	2.5	79	.....	.....	.....	.....	.....	.....
14	2.5	70	2.6	95	.....	.....	.....	.....	.....	.....
15	2.6	81	2.7	110	.....	.....	.....	.....	.....	.....
16	2.7	94	2.8	133	.....	.....	.....	.....	.....	.....
17	2.8	111	2.9	150	.....	.....	.....	.....	.....	.....
18	2.9	125	.....	.....	.....	.....	.....	.....	.....	.....

Lower stumpage prices than those shown are often received for lodgepole-pine timber in many places where only small quantities are required for local use. In Montana the minimum price is approximately $2.50 per thousand board feet. The price of lodgepole-pine stumpage in Forest Service timber sales ranges between this figure and $4.50 per thousand. On State and private lands the average prices are about the same, though in some cases the minimum may be lower than on the National Forests.

The market prices for lodgepole-pine products vary a great deal in different localities. The price of ties is usually fixed by agreements between tie contractors and the railroads. During the last 10 years, however, there has been a steady rise in the prices paid for lodgepole-pine ties. About 5 years ago one large company held a contract to deliver a minimum of 500,000 ties per year at 39 cents on the track, and for all over the minimum number was to receive 45 cents each. Recently the prices paid have ranged from 50 to 65 cents each for first-class ties.

Mine props are usually sold by the linear foot, the pieces varying in diameter from 3 to 6 inches at the smaller end, and in length from 3½ to 16 feet. In general, prices range from 1 to 5 cents per linear foot, according, in some measure, to the size of the prop. At one place in Colorado, for example, the price paid f. o. b. cars is 1 cent per linear foot for 16-foot props, and 1.5 cents per linear foot for 7, 8, and 10 foot props with the small end not less than 4 inches. Representative prices for stulls, lagging, and converter poles in the vicinity of Butte, Mont., are shown in Table 9. Wood usually sells from $5 or $6 per cord delivered to the consumer in town.

In many places there are strong local markets for lodgepole-pine lumber. While the yearly demand is not large, the prices paid are good. In one locality the mill run sells for $17.50 per thousand board feet, and in another for $20.50. While in most places mill run is seldom sold for less than from $15 to $16 per thousand board feet, yet where lumber is considered a by-product, such material is often sold at only a small profit or even at cost.

CHARCOAL MAKING.

In making charcoal the first work is to grade and level up the ground where the pit is to be located. The same place is used two or three times to save work in grading. The wood is cut in 10-foot lengths and hauled to the place where it is to be burned. Each pit accommodates about 50 cords of wood properly stacked and covered with brush, leaves, and dirt. Very complete utilization is secured, since even small branches and twigs are used to fill in chinks and for covering. The actual burning takes about 20 days. Forty bushels of charcoal are produced per cord of wood, weighing 13½ pounds per bushel. Charcoal makers usually work in pairs, for when the pit is burning it must be watched night and day to guard against blow-outs and to change the drafts with varying weather conditions. Two pits are usually burned at one time, a pair of men guarding both.

In charcoal operations near Bernice, Mont., the finished product has to be hauled 8 miles to the railroad at Bernice. One round trip is made a day, with an average haul of 400 bushels. The charcoal is then shipped by freight to Helena in carload lots of 1,600 bushels, at a rate of 15 cents per hundred pounds. Itemized costs of charcoal making in the vicinity of Bernice are as follows:

	Per cord of wood.	Per bushel of charcoal.
Stumpage	$0.50	$0.0125
Cutting and burning:		
Grading	$0.17	$0.0043
Cutting	.90	.0225
Hauling	.45	.0112
Covering	.56	.0140
Burning	1.12	.0280
	3.20	.0800
Hauling to railroad	1.20	.0300
Loading on cars	.05	.0012
Freight, Bernice to Helena	.81	.0202
Total	5.76	.1439
Price received at Helena	6.00	.1500

MANAGEMENT.

OBJECTS.

The two main objects to keep in mind in the management of lodgepole-pine forests are (1) watershed protection and (2) a maximum sustained yield of merchantable timber of the most desirable sizes.

Its wide range and the fact that most of the stands are located at the higher elevations, where rainfall is greatest and the slopes steep, give lodgepole pine a peculiar importance in regulating the flow of streams which have their headwaters in the region. Even the Mississippi receives a considerable part of its summer supply of water from some of these streams. Thus the value of lodgepole-pine forests for the conservation of water is probably as great as their value for timber production, especially when one considers their slow growth and relatively small yield. Nevertheless, lodgepole pine is an important timber tree, and every effort should be made to produce the greatest possible amount of merchantable timber consistent with the maintenance of an adequate forest cover on the watersheds. Many classes of material produced by lodgepole-pine stands, from small poles to the largest timber, can now be marketed, though the demand for each class is not proportionate to the supply. Small stulls, mine props, lagging, converter poles, fence poles, and cordwood, for example, are produced in far greater quantities than the market can absorb, while the demand for large stulls, ties, telephone poles, and saw timber is much greater in proportion to the available supply of this class of material. For this reason every effort should be made to produce large trees, 9 inches or more in diameter. There will inevitably be produced at the same time sufficient small timber to meet every demand.

Throughout most of the lodgepole-pine belt the species should be perpetuated on areas now occupied by it. Exceptions to this rule, however, should be made at the lower and upper edges of the belt, where other species are better suited to the conditions. Thus at the lower elevations the stand should be allowed to revert to Douglas fir and at the upper to Engelmann spruce. Between these two extremes, however, lodgepole pine should be favored against these and such other species as may occur in mixture with it.

ROTATION.

The length of the rotation, which is the period represented by the age of the stand at the time it is to be cut, is determined by the rate of growth of the species under consideration and the purpose for which it is to be used. In the case of lodgepole pine, the tree's slow growth and the need for producing as large size material as possible necessitate a comparatively long rotation. Table 11 shows that the mean annual growth in cubic feet of normal stands in Montana, measured to about 2½ inches in the top, culminates at from 70 to 90 years. A rotation of this length, however, gives few trees 9 inches or more in diameter, and is therefore too short. For material scaled to a 6-inch top diameter limit the mean annual growth in board feet culminates at 130 years, and for material scaled to 8 inches in the top, at from 200 to 210 years. At 130 years only about two-fifths of the scale material is 8 inches or more in diameter at the top end, which is too small a proportion, while at 200 years nearly nine-tenths of the material is of large size, which is more than is needed. The mean annual growth in board feet to a 6-inch top is nearly at its maximum at 140 years, when 53 per cent of the scale material is 8 inches or more in top diameter. This is about as small a proportion of large material as a mature stand ought to produce; at the same time a rotation of 140 years is not unreasonably long. It would appear, therefore, that such a rotation is the best for normally stocked lodgepole stands on average sites in Montana. While yield figures for normal stands in Wyoming and Colorado are not available, it is probable that a rotation of approximately the same length would be satisfactory in these States for the production of mine timbers and ties.

TABLE 12.[1]—*Mean annual growth per acre of normal stands of lodgepole pine on average sites (quality II), at various ages, Deerlodge National Forest, Mont.*

Age.	Mean annual growth.			Amount of scale material 8 inches and over in top diameter.
	Entire tree, top diameter 2½ inches.	Scale material.		
		Top diameter 6 inches.	Top diameter 8 inches.	
Years.	*Cubic feet.*	*Board feet.*	*Board feet.*	*Per cent.*
60	40	81	0	0
70	42	92	0	0
80	42	100	0	0
90	42	105	0	0
100	41	109	15	14
110	39	112	27	24
120	37	113	38	34
130	35	114	49	43
140	33	113	60	53
140 to 200[2]				
200	24	103	90	87
210	23	102	90	88
220	22	100	89	89

[1] Based on Table 9, Department of Agriculture Bulletin 154, "The Life History of Lodgepole Pine in the Rocky Mountains." While the board feet figures are not strictly accurate, they are sufficiently so to serve as a guide in determining the length of rotation.

[2] Between 140 and 200 years there is a constant decrease in the mean annual growth in cubic feet and in board feet to a top diameter of 6 inches, and a constant increase in the mean annual growth in board feet to a top diameter of 8 inches.

It is impossible to fix a single rotation for the ordinary stands now found in the lodgepole-pine region, because of their variable density. Some of the more open stands are ready for cutting before they have reached the age of 140 years, while many of the denser ones will never produce large-sized material without a thinning. For average, well-stocked, unthinned stands on average sites, however, a cutting at 140 years should yield 8,000 or 10,000 board feet per acre, with a fair proportion of large-sized timber, and at the same time leave from 200 to 500 of the smaller trees for future growth. On the better sites the rotation would be shorter and on the poorer sites longer.

METHODS OF CUTTING.

DETERMINING FACTORS.

A number of things have to be considered in determining the best method of cutting lodgepole pine. The forest must be left in such a condition that it will continue to furnish protection to the watershed, the increment of the whole stand must be increased as much as possible, the trees which are left must not be unduly exposed to injury from windfall or sun scald, and the material removed must be of sizes for which there is a ready market. The object of the cutting must also be considered.

HISTORY OF FRENCH GULCH TIMBER SALE.

In order to give a clear idea of the present plan of management for lodgepole pine on the National Forests, the methods employed in the French Gulch timber sale on the Deerlodge National Forest will be briefly described. Owing to the Forest's proximity to Butte, where material of all sizes can be disposed of, it has been practicable, on limited areas at least, to use a number of different systems of cutting. The first cutting followed the selection system.[1] Although the stand was opened up rather heavily in places, there has been but little windfall and the trees are growing faster than before the cutting.[2] This system was not used for a sufficient length of time early in the operation, however, to give it a thorough trial. At about the same time the single-tree system was also practiced in some places, but with unsatisfactory results.

The first definite marking rules were promulgated in October, 1906. They provided for cutting clean strips 150 feet wide, running with the slope, with 75-foot strips between. These latter were divided into blocks 75 feet square, alternate blocks being cut

[1] Properly speaking, the selection system is one used in many-aged stands of tolerant species, from which the large trees are removed in order to admit light to the smaller ones and to start reproduction. The system used on the French Gulch sale area was really a culling or form of partial cutting, but the term "selection system" is the one applied to this method in the lodgepole-pine region.

[2] French Gulch is in the Anaconda smelter-smoke zone, which tends very largely to offset the usual benefits which follow the opening up of a stand.

clean and the remainder left for seed. Even in the seed blocks thinnings were made to remove lagging, converter poles, and large stull trees, so that the seed groups finally consisted of from 30 to 60 trees ranging from 7 to 11 inches in diameter. In exposed situations over 90 per cent of the trees left have been blown down, and many others have died from sun scald or from the drying out of the soil. In the more sheltered situations, particularly where the original stand had been somewhat open, windfall has been much less. This heavy loss from windfall quickly demonstrated the impracticability of such a system for general use in lodgepole-pine stands. These cuttings were not a fair test of the wind firmness of the species, however, for to reduce the number of trees per acre of any species from 500 or 1,000 to about 50, particularly when the individual trees were tall and slender, could hardly result otherwise than in excessive windfall.

The next change in the marking system naturally aimed to eliminate windfall. In the spring of 1909 the strip system was applied. The timber was clean cut in strips, with seed strips from 100 to 150 feet wide left absolutely intact between them. The width of the clean-cut areas was from one to three times that of the seed strips. This system proved successful in reducing windfall to a negligible amount, but in other respects had no advantage over the seed-tree group system. In both systems the operator gradually accumulated a surplus of cordwood and small stulls in excess of the market demand, while the Government lost from the clean-cut areas many small, thrifty trees capable of rapidly developing into large material under better management. At the same time there remained in the seed strips many large, slowly growing trees wanted by the operator and not of use in the stand except to prevent windfall. Neither of the systems is satisfactory in regard to watershed protection, nor does either tend to increase the volume or better the quality of the succeeding stand.

Another important drawback to the systems mentioned was their lack of adaptability to the great variety of conditions found on the sale area. Overdense stands of lagging and converter poles, badly in need of thinning, remained untouched, because a sufficient amount of such material was being obtained from the clear-cut areas. Overdense and moderately dense even-aged stands, uneven-aged stands, and old and young stands were all cut in exactly the same way. For this reason the system of cutting was still further modified in the fall of 1910 and again slightly modified in the summer of 1913. The present marking rules are as follows:

FIG. 1.—SINGLE SEED-TREE METHOD OF CUTTING EMPLOYED EARLY IN THE FRENCH GULCH SALE.

Much windfall resulted, and many trees died of sun scald when exposed to full light. Most of the windthrown trees had been utilized before the picture was taken.

FIG. 2.—SELECTION CUTTING ON THE FRENCH GULCH SALE.

The stand was heavily thinned in 1906. Remaining trees are well spaced and already show increased growth. This thinning was somewhat heavier than those now being made in selection cuttings, but shows very little windfall.

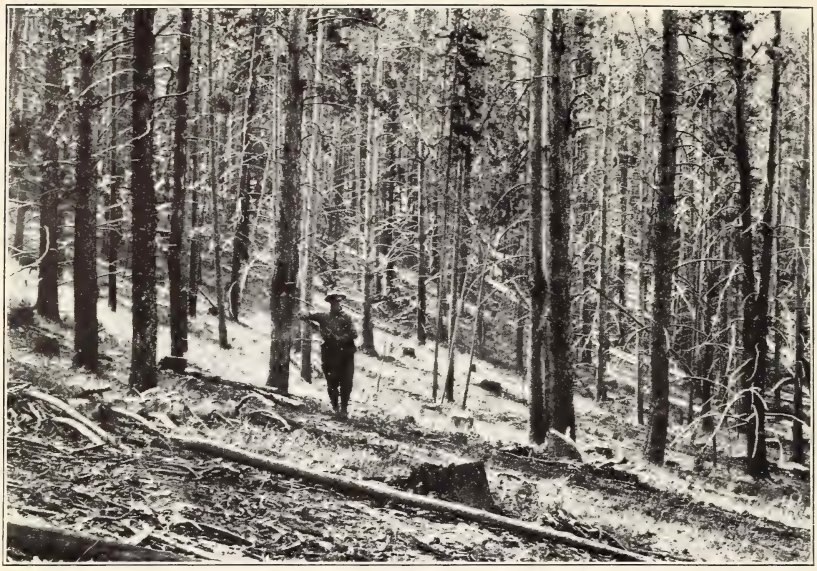

FIG. 1.—SELECTION CUTTING ON THE FRENCH GULCH SALE, WITH BRUSH BURNED AND PRODUCTS REMOVED.

Note low stumps.

FIG. 2.—SELECTION CUTTING ON THE FRENCH GULCH SALE IN WHICH NEARLY ALL TREES WHICH WOULD MAKE 8-INCH STULLS WERE REMOVED.

Note side branches and short clear lengths.

Marking Rules for Lodgepole-Pine Stands on the Deerlodge National Forest.

CLASSIFICATION OF STANDS.

1. *Over-mature stands:*

Such stands are over 160 years in age, contain mainly trees 10 inches or over in diameter, which have evidently passed maturity and are practically at a standstill, if not on the decline.

A very large proportion of the cubic-foot volume of the stand consists of material 8 inches and over in diameter.

In openings which have occurred in the stand from various causes there are frequently groups of young or middle-aged trees which are thrifty and growing fairly rapidly. Owing to the thinning out of the crown cover with old age, there is also usually more or less reproduction on the ground. An example of this class of stands is that found in Julius Gulch, on the French Gulch sale area.

2. *Mature stands:*

Stands of this class usually range in age from 120 to 160 years, but may frequently be older than 160 and in a few cases younger than 120, depending mainly upon the stage of development of the stand, as a whole, as to the production of trees 10 inches or over in diameter.

This classification aims to include stands which contain a large number of trees 10 inches and over in diameter which are now ready for cutting, with a considerable proportion of the whole number of trees, usually over 60 per cent, below 10 inches in diameter and still with crowns sufficiently thrifty to respond with a material increase in the rate of growth to openings which may be made in the stand.

Such stands may range up to 180 or 190 years in age where they have been somewhat crowded in youth.

Groups of young growth are of more or less frequent occurrence in natural openings.

Examples of stands of this class are found in the Jabez Doney sale area, on Dry Gulch, in the Bernice district, and in the selection cuttings along American Gulch, below the main flume, on the French Gulch sale area.

3. *Immature stands:*

Usually under 120 years of age, but classified as young mainly because they do not yet contain any considerable proportion of trees which will yield 8-inch material.

This class is further divided into—

(*a*) Converter pole stands:

Ordinarily from 80 to 120 years in age, but may range up to an age of 160 years where the stand had its origin in overdense reproduction.

There are usually present a few trees from 7 to 10 inches in diameter, but most of the trees have a diameter of less than 8 inches.

Usually there is no reproduction coming in under such stands.

(*b*) Lagging stands:

Such stands usually range in age from 50 to 80 years, but, due to overdensity of reproduction, may be as old as 140 years.

Occasionally there are a few trees from 6 to 8 inches in diameter, but most of the trees are below 6 inches.

OBJECTS OF MARKING.

The main object of cutting done on the Deerlodge Forest will be to secure the greatest possible increase of increment for the Forest, as a whole, but not necessarily for each particular acre cut over considered by itself.

The overmature stands will be cut with the intention of removing the old timber now at a standstill and securing a stand of rapidly growing reproduction in its place.

Mature stands will be cut with the object of removing the larger trees now ripe in size for cutting and retaining the smaller trees so situated that many of them will grow to a diameter of over 9 inches within the next 20 to 50 years. Reproduction is not aimed at, although the manner of cutting will secure it in many openings and will hasten its growth in the many places where it already occurs.

Young stands will be handled by improvement thinnings, strictly with the idea of saving the most promising trees and giving them sufficient room to grow rapidly in the future to good size.

CLASSIFICATION OF EXPOSURES.

The following classification is made as a guide to the men doing the marking, with the object of adjusting the severity of the cutting, in the mature stands particularly, to the purpose of securing safety from windfall.

The prevailing wind direction is southwest for the Forest as a whole, although it may be modified locally by topography.

Especially moist and especially shallow soils increase the danger of windfall and should therefore be given consideration in classifying various areas as to exposure. The presence of former windfalls should also be considered.

Safe exposures:

In this classification are included the bottoms of gulches, as a rule, except where they lie parallel to the course of the prevailing wind for a considerable distance. Slopes to the north and east, or in any direction where short or unimportant and well protected by considerably higher ground not far to windward. Examples of such areas are the bottoms of the gulches and the slopes on the Divide Creek sale area.

Medium exposures:

This includes the larger flat areas, gentle, lower slopes to the south and west, and the minor ridge tops where protected by high hills or mountains not far to windward. Examples are the flats and gentle slopes to the west below the main flume at French Gulch, the minor ridge tops on Divide Creek, and the higher portion of the Dry Gulch sale area.

Great exposures:

The crests of exposed ridges and exposed slopes to south and west not protected by marked topography. Such areas would include the south and west face of Slide Rock Mountain and the ridge between Julius and Vanetti Gulches on the French Gulch sale area.

METHODS OF MARKING.

1. *Overmature—Clean cutting:*

Cut all timber merchantable under the terms of the contract excepting that under 7 inches diameter breast high.

Leave groups of smaller size trees and young growth as carefully preserved as possible.

Leave none of the larger trees as a protection against windfall.

The trees left, together with the seed already in the soil and in the cones of trees cut, will provide for reproduction.

2. *Mature—Selection cutting:*

Cutting will be done only to such a degree as, in the judgment of the marker, will leave the stand safe from windfall, particular attention being paid to exposure.

Cut the larger trees—all 14 inches and over—unless needed to prevent windfall.

Cut trees 10 to 13 inches, unless they are needed to prevent windfall, or unless they are especially sound, thrifty individuals standing where they will profit greatly by the amount of light which they are now receiving or will receive after cutting.

Cut 8 and 9 inch trees only when their removal is desirable for the good of the remaining stand, and when they are entirely acceptable to the operator.

Cut no converter poles or lagging trees, or trees of similar size (7 inches or under), whether green or dead, from stands of this classification. Such material may, however, be utilized at the option of the operator, from the tops of the trees designated for cutting, or from material cut from roadways, banking grounds, etc.

Excepting with the general consent of the operator, expressed as to definite areas, no tree which will not make at least one 8-inch–16-foot piece will be marked for cutting. On the other hand, all defective and limby trees, whose retention in the stand is not desired to prevent windfall, will be marked for cutting if they will yield one 8-inch–16-foot piece.

Small pockets of larger trees may be cut clean. Such patches should not ordinarily exceed a quarter acre in area and will usually be much smaller. These clean-cut patches should not exceed 20 per cent of the cutting area in mature stands, and the cutting in the timber around their edges should be lighter than usual to maintain the windfirmness of the whole stand.

The marker should have constantly in mind the object of leaving the stand in the best possible condition for increased growth after the cutting, for which purpose thrifty crowned trees should be left with as reasonable an amount of growing space as the limitations of the system as above set forth will permit.

Selection marking should be very light around the edges, especially the leeward edges, of parks or clean-cut areas an acre or more in extent.

On "safe" exposures, as defined above, no attention need be paid to windfall, since the other rules will leave sufficient timber on the ground to insure windfirmness of the stand.

On "medium" exposures the marking should be done about as it has been in the selection areas below the main flume at French Gulch, where there are left 70 per cent of the trees 3 inches and over, 62 per cent of the trees 6 inches and over, and 20 per cent of the trees 10 inches and over.

On "great" exposures the cutting should remove approximately 25 per cent less than from the "medium" exposures, or should leave approximately 80 per cent of the trees 3 inches and over, 70 per cent of the trees 6 inches and over, and 40 per cent of the trees 10 inches and over.

The foregoing are general rules as to the amount to be left, and must be adapted carefully to the exposure, soil moisture and depth, topography, and condition of the timber in each case, but the leaving of a sufficient stand to be safe from wind throw will be the primary consideration in all selection marking.

3. *Immature—Improvement thinning* with the object of retaining the best trees and leaving them in the best possible position to grow rapidly to large size.

(*a*) Converter-pole stands:

The marker will mentally select for leaving the best trees, straight, sound trees with considerable clear length and a good crown development for the most part, and will aim to leave such trees as evenly disposed as possible over the area, and at the rate of about 2 per square rod (320 per acre) as an ideal number. All other green trees which will make converter poles (4 to 6 inches diameter breast

high) will then be marked for cutting. No lagging trees will be marked for cutting, for such trees will not interfere with the growth of the larger trees especially selected for leaving. No dead trees will be cut unless they will produce at least one 8-inch–16-foot piece. On account of the difficulty of handling long poles in dense stands, the cutting of frequent skid roads is permissible.

Under this system of cutting no attention need be paid to windfall, for a sufficient number of larger trees together with a large number below converter-pole size will be left to withstand the wind.

(*b*) Lagging stands:

The marker will mentally select for leaving the best individual trees—so far as possible straight, sound trees, with either some clear length or at least without large limbs developed at the base of the tree—and will aim to leave such trees as evenly disposed as possible over the area, and at the rate of 3 per square rod (480 per acre) as an ideal number. All other *green* trees which will make lagging (3 to 5 inches diameter breast high) will then be marked for cutting. No dead lagging will be cut. The cutting of frequent skid roads is permissible. No attention need be paid to windfall.

The result of cutting under this selection system at French Gulch has been to leave a considerably larger number of trees on the ground than under the clear-cutting system, and so placed that the rate of growth of most of them will be increased. The proportion of cordwood and small stulls taken by the operator has been reduced and the total number of large stulls increased as indicated by the following figures:

	Per cent large (8 inches and over).		Per cent small (under 8 inches).	
	Selection cutting.	Clear cutting.	Selection cutting.	Clear cutting.
Number of stulls cut	57	37	43	63
Cubic foot volume of stulls cut	71	51	29	49
Board foot volume of stulls cut	76	57	24	43

By the present method of cutting, 2.67 cords, or their equivalent, are taken with each 100 large stulls; by the clear-cutting method, 4.95 cords were taken. In the selection cuttings, too, the average size of the large stulls is greater than was the case in the clear cuttings. The amount of material of various classes cut under the two systems is given in Table 13. The amount of material and the number of trees of various sizes cut and left by the selection system are shown in Tables 14 and 15.

TABLE 13.—*Material of various classes secured under selection cutting and clear cutting on a representative portion of the French Gulch sale, Deerlodge National Forest, Mont.*

[Average acre based on sample areas actually cut and scaled.]

	Selection cutting.						Clear cutting.	
	Cut.		Uncut.		Total.		Cut.	
	Number.	Volume.	Number.	Volume.	Number.	Volume.	Number.	Volume.
		Cubic feet.		*Cubic feet.*		*Cubic feet.*		*Cubic feet.*
Stulls 8 inches and over	176	1,670	67	546	243	2,216	238	2,135
Stulls under 8 inches	135	602	180	800	315	1,402	340	1,675
5-inch mine props	41	110	115	308	156	418	56	149
Converter poles	7	20	79	238	86	258	203	610
Lagging	89	89	106	106	195	195	303	303
Cordwood	3.3	266	1.9	150	5.2	416	7.8	624
Total		2,757		2,148		4,905		5,496

TABLE 14.—*Per cent of material cut and left in selection cuttings on the French Gulch sale, Deerlodge National Forest, Mont.*

	Per cent cut.	Per cent left.
Cubic-foot volume of stand	56	44
Board-foot volume of stand	64	36
Large stulls	72	28
Cubic-foot volume of large stulls in stand	75	25
Board-foot volume of large stulls in stand	76	24
Green trees 3 inches and over in diameter	30	70
Green trees 6 inches and over in diameter	38	62
Green trees 10 inches and over in diameter	80	20

TABLE 15.—*Number of trees cut and left on an average acre under the selection system, Deerlodge National Forest, Mont.*

Diameter breast-high.	Number of trees.			Diameter breast-high.	Number of trees.		
	Total.	Cut.	Left.		Total.	Cut.	Left.
Inches.				*Inches.*			
3	34	2	32	15	6	6	
4	55	5	50	16	4	4	
5	54	9	45	17	2	2	
6	53	4	49	18	1	1	
7	61	5	56	19	1	1	
8	54	8	46	20	.25	.25	
9	44	10	34	21			
10	31	16	15	22			
11	28	23	5	23	.25	.25	
12	20	17	3				
13	22	19	3	Total	483.5	145.5	338
14	13	13					

Average diameter of trees cut, 11.2 inches.
Average diameter of trees left, 6.8 inches.
30 per cent of trees 3 inches and over cut.
38 per cent of trees 6 inches and over cut.
80 per cent of trees 10 inches and over cut.

In order to determine precisely what form marking should assume at each particular place, a detailed map was made by the men who did the work. Besides showing the different kinds of stands, this map formed a valuable record of the area cut over. The cost of marking, including that of the map, averages about 8 cents per thousand feet. It costs more to mark the trees in winter than in summer, and more for the selection system than for clean-cutting. Compared with the cost in stands of such species as yellow pine, that for lodgepole pine is rather high, owing to the small size of the individual trees. It has been found advisable, with the present system of cutting, to mark rather lightly at first, marking again after the first trees have been cut. This causes no hardship to the operator, for the second marking is done before the choppers finish a strip. It costs slightly more than a single marking, but gives more satisfactory results. The marking rules for the Deerlodge are based upon the requirements of the Butte market. They aim not only to furnish the proper amount of each kind of material needed by the timber purchaser, but also to secure the maximum benefits in the way of increased growth, etc., for the Forest as a whole. This does not mean, of course, that each individual acre cut over is left in the best possible silvicultural condition. To do that, the operator would have to cut a greater proportion of small material than the market could absorb. The cutting in mature stands would yield all the lagging and converter poles needed, so that it would not be possible to secure the thinning of overdense immature stands. Lagging poles, for example, can be secured either by taking very badly suppressed or dead trees of the proper sizes from mature or overmature stands, or by thinning dense young stands. If they are taken from old stands no improvement in the rate of growth of the remaining trees will result; there will simply be a utilization of material which is either at a standstill or already dead. If, however, lagging poles are taken from overdense young stands, the remaining trees will be greatly benefited, the stand being changed from one in which the production of large material is going on very slowly to one in which it is comparatively rapid. For this reason, timber of small diameter should, so far as practicable, be taken in the form of thinnings from the younger stands.

Overmature stands of lodgepole pine on the Deerlodge Forest will not be cut absolutely clean. A number of trees less than 7 inches in diameter will be left on each area. Groups of young growth which have come up in openings will also be left, together with scattered, suppressed seedlings. The live trees which remain after the cutting and the sealed cones on the ground will furnish enough seed to start satisfactory reproduction in the open places. There may be occa-

sional small openings, however, which will not seed up for from 10 to 20 years. The result will be a new stand with a considerable range in age. A number of the 4, 5, and 6 inch trees left standing will undoubtedly be blown down. Such loss, however, will be far less than would be the case if a sufficient number of the larger trees were left uncut to insure the wind firmness of the smaller ones. In the latter event, there would probably be a severe windfall among the larger trees; the cost of logging would be increased, and a considerable part of the producing power of the soil would be lost for a time.

In mature stands, cut under the selection system, windfall will be negligible if the marking is carefully done. In many of the openings seedlings will start and grow vigorously; in other places, where a fair number of trees still remain on the ground, they will grow slowly until released by a later cutting; while in still others the stand will be too dense for reproduction to start. From 15 to 20 years later it will be possible to cut the stand again, at which time the process just outlined will be repeated. Later cuttings will completely remove the original stand, leaving one of many age classes, the latter largely in groups.

When immature stands of lodgepole pine are thinned one or more times, the final stand will contain trees more nearly uniform in size than is the case in virgin stands. When the large trees are removed in one cutting, as outlined for overmature stands, the previous thinnings will have resulted in more or less reproduction, which, together with the seed from cones on the ground and from small trees left standing, will furnish the basis for the next stand. If the large trees are removed in two or three cuttings, reproduction will be secured by the shelterwood system.

Thinnings pay well for themselves in accessible areas near Butte. From 1 acre on which there was a 60-year stand consisting of 2,044 poles, from 25 to 45 feet tall, 1,022 lagging poles were cut. Four hundred and eighty-four (about 3 per square rod) of the largest and most thrifty trees, varying from 4 to 6 inches in diameter and from 35 to 45 feet tall, were left. In addition, there were also left 538 suppressed trees too small to interfere with the growth of the larger ones. This thinning yielded $30.66 per acre in stumpage, and the trees which were left are now splendidly placed to grow rapidly to large size.

Wherever a mature or overmature stand is accessible, and the cost of removing the timber is not great, it is advisable to cut more lightly than indicated by the marking rules, in order that defective and deteriorating trees may be removed and growth stimulated over the largest possible area. Where the timber is more or less inaccessible, however, as is usually the case with lodgepole pine, it is necessary to cut heavily in order to justify the expense of the necessary improvements.

CUTTINGS ON OTHER NATIONAL FORESTS.

In a selection cutting of lodgepole pine on the Medicine Bow National Forest 36 per cent of the original board-foot volume of the stand was removed. In a similar cutting on the Arapahoe National Forest 40 per cent of the original volume was taken. The marking in these cases was considerably lighter than at French Gulch, due to the greater exposure of the timber on the Medicine Bow and to the greater accessibility of that on the Arapahoe. The marking on 22 representative acres on the Bighorn National Forest in Wyoming, in the summer of 1913 provided for the removal of approximately 58.5 per cent of the board-foot volume. Table 15 shows by diameter classes the number of trees and the volume in board feet removed and left on an average acre in the operations on the Medicine Bow National Forest.

TABLE 16.—*Number of trees and volume in board feet removed and left on an average acre in selection cuttings on the Medicine Bow National Forest, Wyo.*

[Based on 97 measured acres.]

Diameter breast high.	Trees cut per acre.				Trees left per acre.	
	Living.		Dead.		Living.	
	Number.	Volume.	Number.	Volume.	Number.	Volume.
Inches.		*Board ft.*		*Board ft.*		*Board ft.*
7	0.71	9	2.18	26	38.70	464
8	.94	23	2.19	55	37.50	932
9	1.50	63	1.54	65	31.05	1,304
10	3.03	194	1.61	103	23.95	1,531
11	2.70	230	1.27	108	15.44	1,312
12	6.76	710	.89	93	9.60	1,007
13	5.36	705	.77	98	6.47	821
14	5.04	776	.38	59	4.71	726
15	2.53	462	.29	53	2.27	412
16	2.10	439	.11	24	1.49	312
17	1.14	275	.20	47	.75	181
18	.74	205	.05	14	.37	102
19	.41	127	.05	16	.14	44
20	.21	70	.05	11	.06	21
21	.06	24	.01	4	.06	24
22	.07	31	.....	.....	.04	18
23	.03	15	.01	5	.....	.....
24	.01	5	.....	.....	.03	16
25	.04	23	.....	.....	.....	.....
26	.01	6	.....	.....	.01	6
28	.....	.....	.....	.....	.01	7
30	.01	8	.....	.....	.....	.....
31	.01	9	.....	.....	.....	.....
34	.01	12	.....	.....	.....	.....
Total..	33.62	4,421	11.58	781	172.45	9,240

BRUSH DISPOSAL.

The object of brush disposal is to leave the cutover area in the best condition to insure reproduction and to protect it from fire and fungi. Brush left scattered haphazard over an area will permit of abundant reproduction, except where the débris is especially deep. Brush piled in windrows prevents reproduction upon the spaces they cover, though reproduction will be secured in the spaces between

FIG. 1.—BURNING A LODGEPOLE-PINE BRUSH PILE UNDER 2 FEET OF SNOW.

FIG. 2.—A BRUSH PILE LIKE THIS WILL LIGHT EASILY AND BURN CLEAN UNDER 25 OR 30 INCHES OF SNOW WITHOUT DAMAGE TO THE REMAINING TREES.

FIG. 1.—CLEAN CUTTING OF LODGEPOLE PINE (FOREGROUND) WITH COMPLETE UTILIZATION TO ABOUT 2 INCHES IN THE TOPS FOR STULLS, MINE PROPS, CONVERTER POLES, AND CORDWOOD.

Note seed strips in background.

FIG. 2.—COMPLETE UTILIZATION OF LODGEPOLE PINE ON A CLEAN-CUT AREA.

Brush pile in center of picture is 12 feet high. Such a pile can be burned in any weather.

FIG. 1.—DENSE STAND OF LODGEPOLE PINE, ABOUT 120 YEARS OLD.

Originally with 1,052 green trees per acre, nearly all under 7 inches in diameter, thinned by the removal of 260 converter poles and 300 lagging poles per acre. The thinning is probably too light to greatly benefit the remaining stand. Heavy thinning brings danger from windfalls.

FIG. 2.—STAND OF LODGEPOLE PINE, ABOUT 120 YEARS OLD.

Six thousand five hundred green trees per acre, badly in need of thinning.

the rows from the seeds from cones remaining on the ground. The same thing is true of brush left in conical piles. To secure reproduction, however, it is not necessary to leave brush piles on the ground; also, such a course is seldom, if ever, necessary in order to prevent erosion. From the standpoint of fire protection it is desirable to burn the brush in practically every case.

Burning brush scattered broadcast exposes the mineral soil. With full sunlight and the opening of sealed cones on the ground, a fairly dense stand of reproduction will be obtained in such cases, although not nearly so dense as that which comes up after a ground fire has killed standing timber, since in the latter case a greater amount of seed is preserved from destruction in the crowns of the trees. Burning an entire area on which the brush has been piled in windrows will result in a moderately dense reproduction between the rows, but no reproduction in the spaces occupied by them. When conical piles are burned the spaces occupied do not immediately come up to young growth.

The foregoing is true of clean-cut areas. Where a part of the stand is left the chances of reproduction are still better. Piling the brush in conical piles and burning it does the least damage to the remaining green trees and reproduction. Moreover, the least amount of mineral soil is exposed, thus avoiding possible over-dense reproduction following seeding from above.

Any considerable amount of brush remaining on a cut-over area greatly increases the fire danger in the remaining stand and for any reproduction which may start. Owing to the very slow decay of brush in the lodgepole-pine region the fire menace continues for a long time if the brush is left unburned. Timber operators familiar with conditions in the lodgepole-pine region say that it costs no more to pile brush for burning under Forest Service regulations than to follow the old method of piling it in windrows, provided the work is well done at the outset. When the brush is not piled properly in the first place it becomes necessary to repile it, which naturally increases the cost. Recently timber operators on the Deerlodge National Forest have been required to burn the brush as the cutting proceeds, whenever weather conditions make it safe to do so. This period of safety covers from seven to nine months in the year. Brush from stull trees is disposed of as fast as the cutting proceeds in any depth of snow encountered in the region, which at times may amount to 6 or 7 feet. In the spring when the snow melts the ground is found to be practically clean. When lagging poles are being cut in snow, however, it is not practicable to burn the tops after the snow accumulates to a depth of about 3 feet, since it is then impossible to carry the tops to the central fire. Even when the snow is less than 3 feet deep it is not advisable to burn where less than 100 poles are being obtained in one place, since there is not enough brush to start a good

fire. Data obtained in actual woods work show that piling brush in winter without burning it costs 69 cents per thousand board feet. With this method, however, the brush must always be repiled when the snow goes off in the spring. Burning as the cutting proceeds costs 74 cents per thousand, but is really cheaper than the other method because it saves the cost of repiling and of burning the following fall, and reduces the cost of skidding.

In summer cutting, brush is gathered in large piles on the clean-cut areas, and in smaller piles in the selection cuttings. Even in the latter case the piles are usually made at least 5 or 6 feet high, with a comparatively narrow base to permit them to shed rain and snow. A small brush pile can only be lighted in the fall if weather conditions are right. In the fall of 1911 the first snowfall on the Deerlodge National Forest occurred in early October, covering the ground to a depth of from 25 to 30 inches, and making it quite impossible to burn small piles. Piles of standard size, however, were lighted without difficulty. On the French Gulch sale the lighting of such piles under approximately 30 inches of snow cost about 6 cents per thousand feet. Another difficulty with small piles is the large number which have to be lighted—a circumstance which naturally tends to increase the cost.

At one time it was the practice to fork into the fire the ends of sticks and other projecting pieces left in the ring at the outer edge of the pile after the fire had burned down. With proper piling, however, only a small amount of such material should remain—not enough to constitute a fire menace. For this reason it is unnecessary to incur the comparatively large expense of having a second crew follow the lighters to fork in the unburned ends. In selection cuttings, large piles of brush can be burned within from 5 to 6 feet of green trees, provided such piles are covered with a good depth of snow. If there is room, however, piles are always built at a greater distance than this from the remaining timber. On the whole, it has been found that fall is the best time to burn brush, though weather conditions in the spring may occasionally be favorable. In the spring of 1912, for example, about 600 acres of old brush on clean-cut areas, at French Gulch, were burned at a cost of 2 cents per thousand feet.

On the Bighorn National Forest, in Wyoming, where selection cuttings have been the rule, the ideal brush pile is considered to be one about 8 feet in diameter at the base and about 5 feet high. The piles are built tepee fashion, with the larger sticks of unmerchantable material stacked up around the outside. With a cut averaging 6,700 board feet per acre, the number of brush piles per acre averaged about 40. In 1910 an area of 1,500 acres was burned on the Bighorn Forest at a cost of 6.9 cents per thousand feet; the next year 3,700 acres were burned at a cost of 3.8 cents per thousand; and in 1911, 4,200 acres were handled at a cost of 3.6 cents per

thousand. The cost varied with the number of brush piles per acre and the depth of the snow. It was found that on an average one man could in one day burn 536 piles under 8 inches of snow, 418 under 10 inches of snow, and 299 piles under 12 inches of snow.

REGULATING THE CUT.

In the existing unmanaged stands of lodgepole pine the arrangement of age classes is never ideal, and a long series of carefully planned cuttings is necessary to convert the irregular forest into a regular or normal one. Certain age classes usually occupy much more than their share of the ground, while one or more classes may be entirely lacking. For this reason the first cuttings in such a stand are, as a rule, based primarily on volume rather than on area. An estimate is made of the actual amount of growing stock on the ground and also of the probable yield during certain periods—usually 10 years—throughout the length of the rotation by the various age classes represented. With these figures as a basis, it is possible to fix the volume which can be cut during each period without exceeding the amount of wood produced. If, through the presence of large bodies of mature and overmature timber, the growing stock is greater than normal, the surplus should be removed by cutting for a few years more than is being produced; while, if through the presence of large bodies of younger age classes, the growing stock is less than normal, the deficiency should be made up by cutting for a time less than is being produced.

The management planned for the timber on the Bernice division of the Deerlodge National Forest furnishes a concrete example of the method of regulating the annual cut during the course of the next rotation. Table 16, which is based on figures secured by an estimating crew which gridironed the area in lines at intervals of one-fourth mile, shows the different classes of timbered and untimbered land on the Bernice division. Table 17 shows the degree of normality, volume, and annual increment of the different age classes found in the timbered area of the division, and Table 18 shows the proposed method of cutting for the next 140 years.

TABLE 17.—*Classification of the land and timberland on the Bernice division, Deerlodge National Forest, Mont.*

LAND.

	Area.	Per cent.
	Acres.	
Timberland [1]	63,051	80.0
Grass land	12,563	15.9
Brush land	912	1.2
Cultivated land	674	.9
Barren land	1,569	2.0
Total	78,769	100.0

[1] 62,491 acres, or 99.1 per cent, productive; 560 acres, or 0.9 per cent, alpine.

TABLE 17.—*Classification of the land and timberland on the Bernice division, Deerlodge National Forest, Mont.*—Continued.

PRODUCTIVE TIMBERLAND.

	Area and yield.	Per cent.	Area.	Per cent.
	Acres.		*Acres.*	
Merchantable			17,761	28.5
Age classes—				
Over 200 years	474	2.7		
160–200 years	2,844	16.0		
120–160 years	14,443	81.3		
Total	17,761	100.0		
Types—				
Lodgepole pine	16,080	90.6		
Douglas fir	1,526	8.6		
Engelmann spruce	155	0.8		
Total	17,761	100.0		
Stand by species—	*1,000 b. f.*			
Lodgepole pine	74,583	80.4		
Douglas fir	9,850	10.6		
Engelmann spruce	7,051	7.5		
Miscellaneous	1,347	1.5		
Total green	92,831	100.0		
Dead	8,749			
	Acres.			
Immature			40,585	64.9
Age classes—				
10 years	1,570	3.9		
20 years	9,742	24.0		
30 years	5,511	13.6		
40 years	7,559	18.6		
50 years	1,412	3.5		
60 years	4,887	12.0		
70 years	1,928	4.8		
80 years	2,448	6.0		
90 years	2,092	5.1		
100 years	3,040	7.5		
110 years	396	1.0		
Total	40,585	100.0		
Suppressed			4,145	6.6
Total			62,491	100.0

TABLE 18.—*Real and normal growing stock and periodic annual increment on the Bernice division, Deerlodge National Forest, Mont.*

Age.	Area.	Normality.	Growing stock.		Periodic annual increment.		Yield at the age of 140 years.[1]
			Real.	Normal.	Real.	Normal.	
	Acres.		*1,000 cu. ft.*	*1,000 cu. ft.*	*1,000 cu. ft.*	*1,000 cu. ft.*	*1,000 bd. ft.*
10 years	1,570	0.67	95	402	9	40	16,662
20 years	9,742	.69	1,815	1,205	121	80	106,476
30 years	5,511	.73	2,293	2,544	121	134	63,448
40 years	7,559	.66	5,687	5,089	284	254	78,920
50 years	1,412	.67	1,731	8,168	65	308	15,058
60 years	4,887	.49	5,747	10,713	136	254	38,090
70 years	1,928	.40	2,267	13,123	42	241	12,215
80 years	2,448	.30	2,468	14,998	31	187	11,633
90 years	2,092	.20	1,582	16,872	18	187	6,628
100 years	3,040	.20	2,481	18,211	18	134	9,631
110 years	396	.20	342	19,283	2	107	1,254
Over 120 (average age 130 years):							
Merchantable	17,761	.35	28,671	61,062	57	147	.....
Suppressed	4,145	.10	1,890	.....	.....	.....	.....
Total	62,491	.....	57,069	171,670	904	2,073	.....

[1] Normal yield, 15,840 board feet at 140 years on sites of average quality; 78.7 per cent of area overstocked; 20.5 per cent of area understocked; 0.8 per cent of area normally stocked.

TABLE 19.—*Volume regulation for the next 140 years on the Bernice division, Deerlodge National Forest, Mont.*

Period.	Stand maturing.	Cutting each decade.	Balance at end of decade.
	1,000 b. ft.	*1,000 b. ft.*	*1,000 b. ft.*
Present (1910)	92,831	20,000	72,831
Decade beginning—			
1920		20,000	52,831
1930	[1] 28,770	20,000	61,601
1940	1,254	20,000	42,855
1950	9,631	20,000	32,486
1960	6,628	20,000	19,114
1970	11,633	20,000	10,747
1980	12,215	20,000	2,962
1990	38,090	20,000	21,052
2000	15,058	20,000	16,110
2010	78,920	70,000	25,030
2020	63,448	70,000	18,478
2030	106,730	70,000	55,208
2040	16,678	70,000	1,886
Total	481,886	480,000	1,886

Average annual yield for rotation, 3,442 thousand board feet for the division, or 55 board feet per acre of productive timberland.

[1] Increment taking place on stands now merchantable, but which will not all be cut for about 50 years (65 board feet per acre added annually on 17,761 acres for 25 years). Sixty-five board feet per acre per annum is approximately the average increment in a stand 0.6 normal on an average site between the age of 120 and 160 years.

It will be observed (Table 17) that a large proportion of the area is taken up with the younger age classes, due partly to heavy cuttings in the last 30 years. On the whole, however, the age classes are fairly well distributed for an unmanaged forest. It will also be seen (Table 18) that none of the older age classes have a high normality. This is because when such stands include over 2,000 board feet per acre they are classed with the merchantable timber, although they may be actually less than 120 years old. The method of volume regulation (Table 19) calls for a moderate cut on the division for 100 years and a much heavier one for the last 40 years of the rotation, without reducing the annual cut at any time. Such a regulation is made necessary by the irregularity in the distribution of age classes. Other divisions of the Forest have a surplus of their area in the older age classes, so that the annual cut for the entire Forest and for the whole rotation can be given the proper degree of uniformity only by applying the regulation to groups of such divisions rather than to each division separately. The figures showing the stand maturing for each 10-year period are taken directly from Table 18, except the figures for 1930, which represent the approximate growth on the mature timber originally on the area. The figures for the real growing stock (present total stand) in Table 18 were obtained by multiplying the normal stand per acre for each age class, as given in Table 9, United States Department of Agriculture Bulletin 154, "The Life History of Lodgepole Pine in the Rocky Mountains," by the average normality (which gave the present stand per acre) and multiplying this result by the actual area occupied by each age class. For example, the normal yield on average sites at 10 years of age is

90 cubic feet, the average normality of the 10-year age class is 0.67, and the actual area occupied is 1,570 acres; consequently, the real growing stock is $90 \times 0.67 \times 1,570 = 94,671$ cubic feet. The real periodic annual increment is determined by multiplying the normal periodic increment per acre, as given in Table 9, United States Department of Agriculture Bulletin 154, by the normality and by the area actually occupied. Thus, for the 10-year age class the real periodic increment is $9 \times 0.67 \times 1,570 = 9,467$ cubic feet.

The normal growing stock is based on the assumption that the forest will be managed on a 140-year rotation, and that in a normal forest each age class should have the same area. This normal area is found by dividing the total area by the number of age classes. Thus: $\frac{62491}{14} = 4,463.6$ acres. The normal growing stock on this area is then found by multiplying the normal yield at any given age (as given in Table 9, United States Department of Agriculture Bulletin 154) by the normal area. For example, the normal yield at 10 years of age is 90 cubic feet and the normal area of a 10-year age class is 4,463.6 acres; consequently, the normal growing stock is $90 \times 4,463.6 = 401,724$ cubic feet. Similarly, the normal periodic annual increment is the normal increment per acre (as given in Table 9, United States Department of Agriculture Bulletin 154) multiplied by the normal area.

The fact that all ages of merchantable timber were lumped together in the estimates and that, as already stated, any stand running 2,000 or more board feet per acre was considered merchantable, necessarily results in a comparatively large area and growing stock being assigned to the 120 to 160 age classes and a correspondingly small area and low normality to the age classes just under 120 years. For this reason the figures for volume increase tend to be conservative. Other reasons why these figures are conservative are that no consideration is given to the effect of future thinnings in young stands, to reproduction in old stands, or to increased growth resulting from selection cutting. Moreover, certain areas less than 0.3 normal are classed as grassland, although they bear an open stand of timber which will actually figure in the final yield. Also, rather open stands of low normality will become better stocked through the filling in of blanks. On the other hand, there will undoubtedly be some losses from fire and other causes.

It will be noticed that the scheme of regulation is presented as though the area would be managed under a clear-cutting system, though actually the cutting will be done largely under a selection system. The reason for this is that it is possible to figure much more readily for a clear-cutting than for a selection system, while, in any event, the main object is to obtain a fairly conservative estimate of the probable volume production, which is likely to be as great under the selection system as another.

Within the 25 National Forests in which lodgepole pine is the most important species the lodgepole-pine type has an estimated area of about 9,000,000 acres. The figures for the Deerlodge National Forest show an average annual increment of about 55 board feet. Assuming that the lodgepole-pine forests throughout the region are producing 50 board feet per acre per annum, 450,000,000 board feet could and should be cut annually, together with a very large amount of material from tops, small trees, and thinnings too small to scale. To this amount can be added about 300,000,000 board feet produced on the 6,000,000 acres of lodgepole-pine type in the 45 National Forests where the species is of commercial but not of primary importance. The grand total of 750,000,000 board feet is approximately 9 times the amount of lodgepole pine now being cut each year.

REFORESTATION.

Repeated fires have left considerable areas within the lodgepole-pine zone practically barren of forest growth. Natural reproduction can not be expected on such areas for many years, and it will be necessary to reforest them artificially if they are to return to usefulness within a reasonable length of time. Where the main object is watershed protection, reforestation work should be confined chiefly to the higher altitudes toward the upper limit of the lodgepole-pine zone, where the forest cover has the greatest protective value. Where the chief object is timber production, the best results will be obtained on the better soils near the central part of the lodgepole-pine zone where the annual precipitation is 21 inches or more. A certain amount of artificial reforestation will also probably be used in the future to supplement natural reproduction after cuttings.

SEED COLLECTION AND EXTRACTION.

The fact that lodgepole pine bears some cones practically every year and a heavy crop every two or three years insures a continuous and plentiful seed supply. The cones may be picked either from felled or from standing trees, or gathered from squirrel hoards. Experience, however, has shown the last method to be the only one by which collecting can be done on a large scale at low cost. Cone collection from squirrel hoards is carried on in the fall, usually during September and October, when the caches are full and easily located in the woods. As much as 15 bushels of cones have been found in a single cache. Cones can usually be bought at contract prices per bushel from local residents who do the collecting. As a rule, one man collects from 3 to 6 bushels per day, the number of cones per bushel ranging from about 1,600 to 2,200. In good years it should be possible to purchase cones for from 30 to 40 cents per bushel, or in exceptionally favorable years for even less. The total cost of cones at the extraction plant should not exceed 50 cents per bushel.

Lodgepole-pine seed is hard to extract from the cones, and a drying temperature of from 140° to 150° F. is necessary before the latter will open satisfactorily. During the process of drying there must, of course, be enough air circulation to remove the moisture given off by the cones. Where only a few hundred bushels of cones are to be handled, any small room, provided it can be made tight, will serve as a dry kiln. Trays with wire-mesh bottoms, on which the cones are spread in a single layer, should be arranged in tiers, so as fully to utilize the available space. Eight hours of drying at a temperature of from 140° to 150° should open the cones to the extent necessary. Hourly thermometer readings should be taken, in order to insure that the proper temperature is maintained. One higher than 150° may injure the seed, while one lower than 140° will not open the cones. Provision must also be made for removing the moist air from the kiln. The latter should be run continuously day and night, since if it is operated intermittently the cost of extraction will be increased. Wherever the cones can be stored in bins with a free circulation of air, it is usually best to defer seed extraction until late in the winter. After two or three months in such bins the cones will have lost a large percentage of moisture merely through natural air drying.

After the cones have been opened in the drying kiln they must be shaken or thrashed out in order to extract the seed. This is done by means of a cone shaker, which consists merely of a revolving box or drum with a wire covering, through which the extracted seeds fall to the ground. The wings can then be removed by sacking the seed loosely and giving it a vigorous kneading. Where a large quantity of seed is handled a cheaper method is to moisten it slightly and rub it through a wire screen with an ordinary scrubbing brush. After being freed of their wings the seeds are dried again. The cleaning of the seed is finally completed either by winnowing it or by running it through a fanning mill fitted with screens of proper mesh in order to remove all foreign matter, such as pine needles, cone scales, broken wings, and dirt.

It is usually cheaper to extract and clean seed in the immediate vicinity of the area where the cones are gathered than to transport quantities of the bulky cones to a central seed-extraction plant. When seed is to be cleaned regularly in large quantities, however, specially constructed drying kilns are best and cheapest in the long run. A number of such permanent seed-extraction plants have been constructed on the National Forests. These include several small plants, with a capacity of about 90 bushels of cones per 24-hour running, and one large plant capable of handling about 200 bushels in 24 hours. In the latter, located on the Medicine Bow National Forest, a hot-air blast is forced through a large, slowly revolving cylinder, so that the cones are dried and the seed extracted at the

same time. The wings are removed and the seed cleaned by machinery. All the plants are located in extensive longepole-pine forests, where a large supply of cheap cones is constantly available.

The cost of extraction varies with the quantity of seed handled, the abundance of the cone crop, and the efficiency of the methods used. In 1911 the total cost of cleaned seed on the Arapaho and Medicine Bow National Forests, the two Forests which handle the largest amounts, was $1.98 and $2.28 per pound, respectively, against $3.82 and $4.27 per pound, respectively, in 1910. In 1912 the cost of cleaned seed on these Forests amounted, respectively, to $1.80 and $2 per pound. In the three States of Colorado, Wyoming, and Montana 2,560 pounds of lodgepole-pine seed were cleaned in 1910, at an average cost of $4.94 per pound, and 3,350 pounds in 1911, at an average cost of $2.76 per pound. This decrease in average cost was due largely to the concentration of the collecting work in a few places. With improved methods of collecting, extracting, and cleaning lodgepole-pine seed can probably be obtained in the future for less than $2 per pound.

TABLE 20.—*Results of germination tests on lodgepole-pine seed collected from National Forests in the Rocky Mountains.*

National Forest.	Germination.		Real value (number of fertile seed per pound).[1]	National Forest.	Germination.		Real value (number of fertile seed per pound).[1]
	Number of days.	Per cent.			Number of days.	Per cent.	
Collected 1910:				Collected 1911—Con.			
Holy Cross	94	80.5	98,700	Shoshone	27	55.2	50,849
Gunnison	90	71.5	65,000		27	48.6	41,030
Leadville	90	76.5	81,700	Collected 1912:			
Shoshone	89	78.0	68,000	Wyoming	43	23.5	16,920
Arapaho	86	67.0	65,700	Arapaho	31	61.4	63,920
Bonneville	44	33.5	33,100	Do	31	52.0	46,040
Collected 1911:					31	55.2	55,970
Wyoming	25	65.0	51,522		31	55.4	57,759
Arapaho	27	74.6	66,793	Leadville	31	52.8	59,084
	27	36.8	17,644		31	65.6	68,100
Hayden	27	82.2	49,887		31	58.4	61,600
	27	24.6	21,981		31	61.0	66,200
Leadville	27	43.8	43,536	Medicine Bow	31	67.4	67,150
	27	76.6	71,661		31	71.6	67,200
Medicine Bow	27	66.6	63,404		31	59.2	54,560
	27	24.2	23,355		31	58.0	47,250
Routt	27	68.8	56,485				

[1] Obtained by multiplying the total number of seed per pound by the germination per cent.

Lodgepole-pine seed collected in different localities, under different conditions, shows wide variation in its capacity to germinate, as shown in Table 19. For this reason every lot of seed before being used in the field or in the nursery should be tested to determine the number of fertile seed per pound. The seed collected in 1911 was tested only for a period of 27 days, since experiments had shown that by far the greater amount of germination occurred within this time.[1]

[1] The germination per cent obtained from a limited test of this sort is often called "germination energy," as distinguished from "germinative capacity," the latter being the germination per cent secured when the test is allowed to run for a much longer period.

A test limited to a certain number of days is not only much cheaper than a longer one, but gives figures of more practical value in actual sowing operations either in the nursery or in the field. This is because the figures for short tests are based on the behavior of the more vigorous, active seeds, which may be counted on to germinate early under soil conditions perhaps not favorable enough to induce germination of the more sluggish seeds in any reasonable period of time.

DIRECT SEEDING.

Direct seeding is the simplest method of reforestation, and can be used wherever conditions are such as to make it practicable. It is far less certain of success than planting, however, and should be used only on the most favorable sites. Good germination is often difficult to secure, and there is always the likelihood that the seed will be eaten by rodents. Moreover, the young seedlings which come up are exposed to damage from drought during the first growing season and to winterkilling during the first winter. Areas best adapted to direct seeding with lodgepole pine are those where a large proportion of the mineral soil is exposed. This condition is seldom found, however, outside of burns not more than 2 or 3 years old. As a general thing, areas in need of reforestation bear a more or less heavy covering of grass, herbs, and shrubs. Such a cover, particularly when it takes the form of a dense sod, is a serious obstacle to direct seeding, since it prevents seeds from reaching the mineral soil, and after germination competes with the seedlings for the available moisture. The shade cast by a light covering of shrubs or trees, on the other hand, may be beneficial to young lodgepole-pine seedlings by preventing the surface soil from drying out. An open stand of aspen affords an excellent shelter, provided it is not so dense as to interfere with the thrifty development of the seedlings after their establishment. The less favorable the moisture conditions, the greater, of course, is the need for some sort of ground cover.

The season for sowing, while of less importance than either the site or the method, nevertheless has considerable influence on the result. The seed should be sown at a time to insure that the maximum amount of moisture will be available for the young seedlings immediately upon their appearance. At the lower and drier altitudes the best time for sowing is either in the fall (September or October) or in the winter on the snow. At the higher altitudes the best time is either in the winter or in late spring or early summer (May or early June). Experiments by the Forest Service covering a wide range of methods indicate the best to be seeding in prepared spots and broadcasting on snow. The spots are usually spaced from 4 to 6 feet apart each way, requiring from one-half to 1 pound of seed per acre. Broadcasting on snow is practicable only on very

recent burns or on other areas where the seed can easily reach the mineral soil. In such cases, sowing should be done in late winter or early spring, when the surface of the snow is thawing and the seed will sink in, and preferably at a time when there is a likelihood of another fall of snow. When the snow finally leaves the area, the seed is washed into the soil, and conditions are favorable for early germination. The seed is usually broadcasted at the rate of two fertile seeds per square foot, equivalent to from 2 to 3 pounds of seed per acre.

Every area broadcasted with seed must be protected from rodents, such as squirrels and field mice, until after the seed has germinated. Many of the early failures in reforestation were due to the depredations of small rodents that devoured the seed as quickly as it was sown. For this reason every seeded area should be poisoned as a measure of protection.[1] This should be done several weeks before the seed is sown, and preferably again after it is in the ground. The seeded areas should also be protected against the grazing of livestock, and, after the small seedlings appear, against fire.

In 1910, 630 acres in the three States of Colorado, Wyoming, and Montana were reforested to lodgepole pine by direct seeding, at an average cost of $10.77 per acre. In 1911, 640 acres in these States were seeded at an average cost of $8.68 per acre. These costs are abnormally high, since much of the work was experimental, and in many cases unnecessarily large amounts of seed were used. Under ordinary conditions it should be possible to carry on direct seeding by the two methods described within the following limits of cost:

	Cost per acre.			
	Seed spots.		Broadcasting.	
Seed (at $2 per pound)	$1.00 to $2.00		$4.00 to $6.00	
Seed sowing	2.50	4.50	.25	.75
Poisoning rodents	.10	.15	.10	15
Total	3.60	6.65	4.35	6.90

Where the area to be seeded is very rough and steep, or is covered with fallen timber or bowlders, the maximum costs just given may sometimes be exceeded. In many cases, also, it will be necessary to reseed certain portions of the area in order to secure a satisfactory stand. Fail spots should not be reseeded, however, until two or three years after the first sowing, since a portion of the original seed often lies over for a year before germination.

[1] Information regarding the best methods of poisoning rodents is contained in Forest Service Bulletin 98, "Reforestation on the National Forests"; Bureau of the Biological Survey Circular 78, "Seed Eating Mammals in Relation to Reforestation"; and Farmers' Bulletin 484, "Some Common Mammals of Western Montana in Relation to Agriculture and Spotted Fever."

TABLE 21.—*Results of direct seeding of lodgepole pine by various methods in National Forests in Colorado and Montana.*

National Forest.	Acres sown.	Site.		Method of sowing.	Protection against rodents.	Date of sowing.	Results.	
		Elevation.	Character.				Average stand of seedlings.	Date counted.
		Feet.					*Number per acre.*	
Arapaho	0.90	9,900	Recent burn, mineral soil exposed	Seed spots	Poisoned	June, 1911	13,050	July, 1913
	12.00	9,900	do	Broadcast on snow	None	May, 1911	2,000	Do.
	51.70	9,000	14-year-old burn, aspen cover	do	do	April 15, 1912	1,767	June, 1913
	78.00	9,500	do	do	do	April 16, 1912	2,250	Do.
	30.00	9,000	do	do	do	April 11, 1912	5,200	Do.
	20.06	9,000	do	Seed spots	do	June, 1912	3,500	Do.
	24.90	9,600	Cut over 4 years ago	Broadcast on snow	do	April 24–25, 1912	1,350	Do.
Colorado	34.00	9,400	Old burn, heavy ground cover	Broadcast on ground	Poisoned, 1910.	Spring 1910 and 1911	2,000	July, 1913
	21.33	9,200	Old burn, grass and weeds	Seed spots	Poisoned	September, 1912	1,540	Do.
	10.00	10,000	Old burn, scattering grass	do	do	June, 1912	2,100	Do.
	20.00	10,000	do	do	do	do	861	Do.
	40.00	9,600	Grass, etc	Broadcast on ground	do	May, 1912	2,838	August, 1912
Durango	2.00	8,000	Yellow pine type, heavy oak brush	Seed spots	do	November, 1910		July, 1912
Gunnison	.20	9,600	Old burn, mineral soil exposed	do	do	June, 1911	2,596	Sept., 1912
Leadville	22.00	9,800	Very old burn, light aspen cover	do	do	November, 1910	1,130	June, 1913
	10.00	9,500	Old burn, aspen cover	do	do	May, 1912	180	July, 1913
	50.50	10,000	do	do	do	do	370	Do.
	50.00	9,500	do	do	do	do	560	Do.
Absaroka	50.00	7,000	Clay loam	Broadcast on ground	None	March, 1911	350	May, 1913
Beartooth	2.60	7,200	do	Corn planter	Poisoned	May, 1911	0	Sept., 1912
	4.75	7,000	Gravelly loam	Broadcast on ground	do	do	20	May, 1912
	12.12	7,500	do	do	do	November, 1911	0	July, 1912
	15.00	7,200	Sandy loam	Corn planter	do	May, 1912	0	
Beaverhead	5.00	7,000	Gravelly loam	Seed spots	do	April, 1911	0	May, 1912
	23.00	7,000	do	Corn planter	do	do	0	Do.
	43.00	7,000	do	Broadcast on snow	do	do	0	Do.
	13.00	7,000	Limestone gravel loam	Seed spots	do	do	0	Do.
Madison	50.00	6,500	Gravelly loam	Broadcast on snow	Seed coated with red lead.	March, 1911	0	Do.

Table 21 shows the result of direct seeding on some of the National forests in Colorado and Montana. It will be seen that in the former State the direct seeding of lodgepole pine has been attended with a fair degree of success, while in the latter it has been practically a total failure. It is not easy to account for this difference, though it seems that the greater rainfall of Colorado has had its effect. Though enough reforestation work has not yet been done to demonstrate conclusively the possibilities of direct seeding, it seems certain that in Montana a more satisfactory stand can be secured at less cost by setting out plants raised in a nursery than by sowing seed directly on the site, while in Colorado, on the other hand, direct seeding should give the best results, provided conditions are favorable. Under adverse conditions, of course, reforestation by direct seeding can not be expected to prove successful even in Colorado.

PLANTING.

While comparatively little lodgepole pine has been planted, the experiments conducted by the Forest Service prove pretty conclusively that this method of reforestation will be successful. If grown on a large scale, 3-year-old transplants can be raised at a cost of from $3 to $5 per thousand. Field planting at the rate of 1,000 to the acre costs from $6 to $8 per thousand, making the total cost per acre from $9 to $13. This is considerably more than the cost of direct seeding where the latter is successful the first time, yet so few sites are fitted for seeding that planting will in most places cost less in the long run. If the ground has to be seeded several times to obtain a satisfactory stand, planting will have a great advantage in cost.

One obstacle to artificial reforestation with lodgepole pine is the tree's slow rate of growth. This means that interest charges on the original investment must be carried for a long time, and also that yield is comparatively small. Lodgepole pine will yield about 10,900 board feet of timber per acre in 100 years, worth $4 per thousand. With a cost for planting of $9 per acre and a charge of 5 cents per acre per year for fire protection, a planted stand of lodgepole pine will yield only 1¼ per cent on the money invested. Western white pine, on the other hand, with a cost for planting of $7 per acre and a charge of 10 cents per acre per year, yields 75,000 board feet per acre in 100 years, worth $5 per thousand, or a return of 6¼ per cent on the money invested. With the rotation of 140 years which would ordinarily be required for lodgepole pine, the comparison would be still more unfavorable to it. Lodgepole pine will hardly be planted on a large scale until large areas of more productive sites have been reported.

Where it is desired to reestablish the forests over a large area at the lowest cost, small groups of 5 or 6 trees may be planted, the groups 40 or 50 feet apart. Such groups could be counted on to begin the reseeding of the remainder of the area as soon as the trees

become old enough to bear fertile seed, usually in 15 or 20 years. Planting by this method would require from 125 to 150 seedlings per acre, and should cost about $2.

PROTECTION.

FIRE.

Although fire is the principal agent in aiding lodgepole pine to maintain its existence in many places, it is also the most destructive agent in mature lodgepole-pine stands. Besides the active measures taken to prevent and extinguish fires, such as lookout stations, telephone lines, roads and trails, patrol, and the like, certain coordinate lines of forest work may be handled in a manner to insure that the fire danger will be kept at the minimum. The most important of these in the case of lodgepole pine is the grazing of live stock, particularly sheep. In the lodgepole-pine region fire almost invariably spreads by means of grass and weeds. A grass fire travels very rapidly and soon spreads over large areas. The grass of the lodgepole-pine region becomes sun-cured early in July and dries very rapidly after summer showers which dampen other inflammable material for several days. Thorough grazing on the dangerous areas by sheep would dispose of most of the inflammable material. Old grass left over from the previous year is particularly inflammable and makes a very hot fire. Particularly heavy grazing along trails, secondary ridge tops, and certain section lines would be a means of securing fire lines at frequent intervals. When grazing in the timber sheep trample and wear out the down litter and other débris, greatly hastening its decay.

In addition to the grass which grows in and near the timber, pine needles and other débris form an inflammable ground cover. A fire in needles alone travels slowly and is easily controlled. Where, however, there is also a considerable amount of débris, such as old tops and down timber under dense young stands, the heat from below sometimes starts crown fires, though this is rare in lodgepole pine. Fires on cut-over areas where the brush has been piled and burned are easy to control. Where the brush has been well piled and not burned there is danger of a hot fire which will kill many green trees near the piles. Such a fire is harder to handle, of course, than one on a cleaned-up area, but it is by no means as hard to handle as one on an area where the slash is left in windrows or scattered over the ground. Roads and skidding trails constructed in connection with cuttings and thinnings will act as fire breaks. Much less débris is likely to accumulate in the well-spaced, moderately open stands which come up after cutting than in the over-dense stands resulting from fire. By the time the lodgepole-pine region has been cut over once under Forest Service regulations, with the proper amount of grazing, the fire danger will have been very much reduced, even though no further advance is made in other means of prevention and control.

INSECTS.

Much can be done to prevent serious insect damage in lodgepole-pine stands merely by keeping the forests in the best silvicultural condition. The removal of over-mature and unhealthy trees and the thinning of overstocked stands will leave the more thrifty timber, the kind best able to resist insect attacks. When an outbreak does occur, measures of control should be taken promptly, since an insect infection can be dealt with most effectively and with least cost in its incipiency. Whenever possible the bark should be removed from attacked trees. This may be done either after the trees are felled or while they are still standing, provided the infested parts can be reached from the ground. Infested trees can frequently be sold or given away under free use, or used for administrative purposes, although in some cases it may be necessary to treat them without any prospect of their immediate utilization.

Where an insect attack is widespread, a specially organized campaign may be necessary. When the mountain pine beetle (*Dendroctonus monticolæ*) attacked the lodgepole pine in the Bighole Basin in the Deerlodge and Beaverhead National Forests in Montana, in 1912, 2,426 trees were treated in late June and in early July, of which 25 per cent, averaging 13 inches in diameter, were felled and peeled for a distance of about 24 feet from the stump. The cost of this work, including brush disposal, amounted to about $1.75 per tree. The remainder of the trees, averaging 11 inches in diameter, were peeled as they stood to a height of about 8 feet from the ground, at a cost of 39 cents per tree. Trees as small as 6 inches in diameter were infested, but no trees less than 8 inches in diameter were treated. The costs in this case were excessively high, owing to the very short time in which the work could be done, the lack of suitable tools, and to several changes in plan. In 1913, during the 45 days following May 21, a total of 23,393 trees, averaging 12 inches in diameter and standing on an area of 60,000 acres, were peeled as they stood to an average height of 12 feet, at an average cost of 33⅓ cents per tree. The aim of this work was not to destroy the insects entirely, but to reduce their numbers to a point where their natural enemies, such as birds and parasites, would be able to keep them under control. It is believed that this has been accomplished. The total cost of the work during the two seasons was $9,540.67. This expenditure has rendered safe for the present an overmature stand which will almost surely bring a stumpage price of over $1,000,000 within the next 20 years, provided the timber is kept green. During 1913, in the course of a similar control project in lodgepole and yellow pine on the Ochoco National Forest in Oregon, 12,873 trees were treated at an average cost of 50 cents each, on an area of about 12,000 acres. In this case the trees were felled and peeled, and the bark burned.

DISEASES.

Little can be done to protect the lodgepole-pine forests from fungi and mistletoe, except to remove whenever practicable all diseased trees and to keep cut-over areas free from débris. Partly merchantable trees attacked with rot should be felled and the sound portions utilized. All infected trees, however, whether merchantable or not, should be felled, if possible, as a measure of protection to the remaining stand.

GRAZING.

The grazing of live stock is usually helpful in a lodgepole-pine stand as a means of reducing the fire danger. On recently cut-over areas, however, sheep grazing should be carefully regulated, if allowed at all, until reproduction is well established. Where an unusually heavy sod is an obstacle to reproduction, heavy grazing by sheep may be a means of exposing the mineral soil.

SUMMARY.

Lodgepole pine is the most important commercial species over a large part of the Rocky Mountains. It is already used for railroad ties, mine timbers, and fence posts, and in the future will no doubt be extensively employed for telephone poles and rough lumber. In addition to their commercial value, the lodgepole-pine forests are of great importance as a protective cover on the watersheds.

Overmature stands of lodgepole pine should be cut practically clean. Mature stands should be cut under the group selection system in order to prevent an overproduction of small material and to secure increased growth of the smaller trees left. In marking under this system, the aim should always be to insure against excessive windfall. Overdense young stands should be thinned whenever practicable. As a general thing, no special measures need be taken to secure reproduction. All brush on timber-sale areas should be piled and burned. Where artificial reforestation is necessary, planting will usually be the most satisfactory method, though direct seeding may give satisfactory results on exceptionally favorable sites. Protection from fire is the first step in systematic forest management.

APPENDIX.

VOLUME TABLES.

Table 22 shows the contents in board feet of trees of different diameters and containing different numbers of 16-foot logs. For trees from 7 to 9 inches in diameter, inclusive, and for all one-log trees, the table is based on 555 trees measured in Deerlodge County, Mont., with an average stump height of from 0.5 to 1 foot, and an average top diameter inside the bark of 6 inches; for all trees 10 inches and over in diameter and containing more than one 16-foot log, it is based on 1,808 trees measured in Gallatin County, Mont., with an average stump height of from 1.4 to 2.2 feet and an average top diameter inside the bark of from 6.2 to 6.6 inches.

TABLE 22.—*Average contents in board feet (Scribner Decimal C rule) of lodgepole-pine trees of various diameters and 16-foot log contents, Gallatin and Deerlodge Counties, Mont.*

Diameter breast high.	Number of 16-foot logs.					Diameter breast high.	Number of 16-foot logs.				
	1	2	3	4	5		1	2	3	4	5
	Contents in board feet.						Contents in board feet.				
Inches.						*Inches.*					
7	10	...	...	...	...	16	90	135	190	270	365
8	20	40	...	...	...	17	105	150	210	305	405
9	25	50	...	...	...	18	120	165	240	340	445
10	35	60	90	125	...	19	135	195	270	375	485
11	45	70	100	140	...	20	150	220	300	410	525
12	50	80	115	160	...	21	170	245	330	450	565
13	60	90	130	180	...	22	190	...	365	485	605
14	70	105	150	210	280	23	...	...	400	525	650
15	80	120	165	240	325	24	...	...	440	565	690

Table 23 shows the contents in cubic feet and in board feet of trees of various diameters and total heights in the Deerlodge and Gallatin National Forests, Mont. The volume in cubic feet includes the entire contents of the tree (exclusive of bark) from the top of the stump to a top diameter of from 2 to 3 inches inside the bark. The volume in board feet shows the amount of scale material included in the tree to a top diameter of 6 inches inside the bark. Besides the board-foot contents there is always a small amount of additional material in the tops which can be used for lagging poles, converter poles, cordwood, etc., when such material is marketable.

TABLE 23.—*Average contents in cubic feet, to a top diameter of from 2 to 3 inches inside bark and in board feet (Scribner Decimal C rule) to a top diameter of 6 inches inside the bark, of lodgepole pine trees of various diameters and total heights, Deerlodge and Gallatin National Forests, Mont.*

Diameter breast high.	Total height of trees in feet.															
	30		40		50		60		70		80		90		100	
Ins.	*C.ft.*	*B.ft.*	*Cu.ft.*	*B.ft.*	*Cu.ft.*	*Bd.ft.*	*Cu.ft.*	*B.ft.*	*Cu.ft.*	*Bd.ft.*	*Cu.ft.*	*Bd.ft.*	*Cu.ft.*	*Bd.ft.*	*Cu.ft.*	*Bd.ft.*
3	1.0	.....	1.3	.....	1.8	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
4	1.5	.....	1.7	.....	2.2	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
5	2.1	.....	3.0	.....	4.0	.....	5.4	.....	.....	.....	.....	.....	.....	.....	.....	.....
6	2.7	.....	3.3	.....	5.1	.....	6.0	.....	8.0	.....	.....	.....	.....	.....	.....	.....
7	4.0	.....	5.5	.....	7.3	10	9.6	30	11.2	40	.....	.....	.....	.....	.....	.....
8	4.8	.....	7.5	20	9.5	30	11.4	40	14.0	50	15.8	60	.....	.....	.....	.....
9	.....	.....	8.9	25	11.0	35	14.2	50	17.0	60	19.1	75	.....	.....	.....	.....
10	.....	.....	.....	.....	12.5	45	16.6	60	20.0	75	23.0	90	.....	.....	.....	.....
11	.....	.....	.....	.....	14.0	60	19.9	70	23.0	90	27.4	105	.....	.....	.....	.....
12	.....	.....	.....	.....	17.0	70	22.2	85	26.8	105	32.0	130	36.0	165	.....	.....
13	.....	.....	.....	.....	21.0	90	26.0	105	30.6	130	37.0	160	42.0	190	.....	.....
14	.....	.....	.....	.....	.....	.....	30.0	125	34.2	155	42.0	190	48.0	230	58.0	290
15	.....	.....	.....	.....	.....	.....	.....	.....	38.4	180	47.0	220	55.0	270	65.5	340
16	.....	.....	.....	.....	.....	.....	.....	.....	42.5	205	52.0	250	61.0	310	79.9	395
17	.....	.....	.....	.....	.....	.....	.....	.....	46.5	230	57.0	280	67.5	350	79.0	450
18	.....	.....	.....	.....	.....	.....	.....	.....	51.5	250	62.6	315	74.0	390	86.0	510
19	.....	.....	.....	.....	.....	.....	.....	.....	56.0	275	68.0	350	80.0	430	93.0	600
20	.....	.....	.....	.....	.....	.....	.....	.....	62.0	300	73.0	385	87.0	470	100.0	.....

Table 24 shows the contents in board feet and props of trees of various diameters on three different quality sites in the Arapaho National Forest, Colo. In applying this table to any given stand, the heights of a few trees of different diameters should be measured and compared with the heights given in the table, in order to determine the site quality of the stand being measured. If, as estimating progresses, the average height of the stand changes materially, new height measurements should be taken and the figures applicable to the new site used. This table is based on 1,275 trees cut from overmature stands (about 200 years old) of moderate density. The height of a tree of a given diameter varies with its age, while the relation between its diameter and height, and consequently between its diameter and volume, varies with the density of the stand. Height alone, moreover, does not determine site quality. For these reasons the table is applicable only to the region in which it was made and to stands similar to those in which the figures were secured. Tables based on diameter, and total height, or diameter and number of logs, have a much wider application. The present table allows 8 per cent of defect for old timber, but if unusually defective timber is encountered additional allowance must be made. The volume in board feet includes all of the tree from a stump height of 1 foot to a diameter of 6 inches in the top; the remainder of the tree down to a diameter of 5 inches in the top is given as prop material, expressed in linear feet.

TABLE 24.—*Volume of lodgepole-pine trees of various diameters in board feet (Scribner Decimal C rule) and linear feet of props on three site qualities, Arapaho National Forest, Colo.*

Diameter breast high.	Site quality I.			Site quality II.			Site quality III.		
	Board feet.	Props, linear feet.	Height of tree.	Board feet.	Props, linear feet.	Height of tree.	Board feet.	Props, linear feet.	Height of tree.
Inches.			*Feet.*			*Feet.*			*Feet.*
6	0	20	50	0	18	41	0	15	32
7	25	15	56	20	13	48	15	11	37
8	45	12	62	35	10	53	30	10	42
9	65	10	68	55	10	58	45	10	47
10	70	10	73	75	10	62	60	10	51
11	120	11	77	95	10	66	75	10	55
12	150	12	80	120	10	69	90	10	59
13	180	12	84	145	10	72	115	10	62
14	210	10	87	170	10	75	140	10	64
15	240	13	89	200	10	77	165	8	66
16	275	14	91	235	10	79	190	8	68
17	315	13	93	270	10	81	215	6	69
18	360	12	94	305	10	82	245	6	70
19	405	12	95	340	8	83	270	6	71
20	445	13	96	375	6	84	300	6	72
21	490	12	96	405	6	85	.....	.....	.....
22	530	13	96	440	6	86	.....	.....	.....
23	575	14	97	.....	.....	.....	.....	.....	.....
24	615	15	97	.....	.....	.....	.....	.....	.....

Table 25 is similar to Table 23, except that it represents an average stand without division into site qualities, and includes prop material to a top diameter of 4 inches.

TABLE 25.—*Volume of lodgepole-pine trees of various diameters in board feet (Scribner Decimal C rule), and in linear feet of props on average sites, Medicine Bow National Forest, Wyo.*

Diameter breast high.	Board feet.	Props, linear feet.	Diameter, breast high.	Board feet.	Props, linear feet.
Inches.			*Inches.*		
5	.....	8	13	127	8
6	5	17	14	154	8
7	12	18	15	182	8
8	25	36	16	209	6
9	42	10	17	240	6
10	64	8	18	276	5
11	85	8	19	308	7
12	105	8	20	342	4

Table 26 shows the average number of ties and the amount of prop material, expressed in board feet, for trees of different diameters irrespective of height. The table is based on about 90,000 old trees cut in extensive logging operations on the Medicine Bow National Forest, and includes allowance for all defect.

TABLE 26.—*Average number of ties (7″×7″×8′) and board feet of prop material in lodgepole pine trees of various diameters, Medicine Bow National Forest, Wyo.*

Diameter, breast high.	Number of ties.	Prop material.	Diameter, breast high.	Number of ties.	Prop material.
Inches.		*Board feet.*	*Inches.*		*Board feet.*
10	1.7	13	14	3.6	13
11	2.0	14	15	4.3	12
12	2.4	14	16	4.8	11
13	3.0	14	17	5.0	10

Table 27, which is based on 894 trees, shows the number of ties (including about 25 per cent second-class ties), and of prop material expressed in linear feet, for trees from 10 to 15 inches in diameter and from 50 to 90 feet in height.

TABLE 27.[1]—*Average number of first and second class railroad ties and amount of mine prop material in lodgepole pine, Medicine Bow National Forest, Wyo.*

Diameter breast high.	Total height of trees.									
	50 feet.		60 feet.		70 feet.		80 feet.		90 feet.	
	Ties.	Props.	Ties.	Props.	Ties.	Props.	Ties.	Props.	Ties.	Props.
Inches.	*No.*	*Feet.*	*No.*	*Feet.*	*No.*	*Feet.*	*No.*	*Feet.*	*No.*	*Feet.*
10	2.0	17	2.3	21	2.5	25	3.0	29	.....	.....
11	2.4	13	2.7	18	3.0	21	3.6	25	4.0	28
12	2.8	12	3.2	15	3.5	19	4.1	21	4.5	24
13	3.3	11	3.6	14	4.0	17	4.7	19	4.9	21
14	3.7	11	4.0	13	4.5	15	5.1	17	5.4	19
15	4.0	11	4.4	13	5.0	14	5.5	15	5.8	17

[1] From Forest Service Circular 126.

FORM TABLES.

Table 28, based on 735 trees, shows the butt taper in trees of different sizes, and is useful for estimating the diameter breast high when only the stumps remain. While the table is based on measurements taken in Wyoming, it has been found to be reliable for Montana, and is probably so for Colorado.

TABLE 28.[1]—*Butt taper of lodgepole pine as shown by diameter outside bark, Medicine Bow National Forest, Wyo.*

Diameter breast high.	Height from ground.					Diameter breast high.	Height from ground.				
	1 foot.	2 feet.	3 feet.	4 feet.	5 feet.		1 foot.	2 feet.	3 feet.	4 feet.	5 feet.
	Diameter.						Diameter.				
Inches.	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*
5.....	5.5	5.4	5.2	5.1	4.9	12.....	13.3	12.5	12.2	12.1	11.9
6.....	6.6	6.4	6.2	6.1	5.9	13.....	14.4	13.6	13.2	13.1	12.9
7.....	7.8	7.4	7.2	7.1	6.9	14.....	15.6	14.7	14.2	14.1	13.9
8.....	8.9	8.4	8.2	8.1	7.9	15.....	16.8	15.8	15.3	15.1	14.9
9.....	10.0	9.4	9.2	9.1	8.9	16.....	18.0	16.9	16.4	16.1	15.9
10.....	11.1	10.4	10.2	10.1	9.9	17.....	19.3	18.1	17.5	17.1	16.9
11.....	12.2	11.5	11.2	11.1	10.9						

[1] From Forest Service Circular 126.

Table 29 shows the stem taper of lodgepole-pine trees of different diameters breast high. Such a table can be used as a basis for constructing volume tables in terms of any desired unit, and is also useful as showing at what distance from the ground any given diameter occurs, in trees of different diameters and heights.

TABLE 29.—*Stem taper of lodgepole pine as shown by diameter inside bark, Gallatin and Deerlodge Counties, Mont.*[1]

TREES 50 FEET IN HEIGHT.

Diameter breast high.	Height from ground.										
	5 feet.	10 feet.	15 feet.	20 feet.	25 feet.	30 feet.	35 feet.	40 feet.	45 feet.	50 feet.	Basis.
Inches.	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Trees.*
7	6.8	6.4	5.9	5.5	.....	.....	.....	.....	.....	.....	8
8	7.8	7.3	6.7	6.2	5.5	.....	.....	.....	.....	.....	8
9	8.8	8.2	7.6	6.9	6.2	5.5	.....	.....	.....	.....	7
10	9.7	9.1	8.4	7.7	7.0	6.2	5.4	.....	.....	.....	.....
11	10.7	10.0	9.2	8.4	7.7	7.0	6.2	5.3	.....	.....	10
Total	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	33

TREES 60 FEET IN HEIGHT.

Diameter breast high.	Height from ground.										
	5 feet.	10 feet.	15 feet.	20 feet.	25 feet.	30 feet.	35 feet.	40 feet.	45 feet.	50 feet.	Basis.
Inches.	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Trees.*
7	6.8	6.6	6.4	6.0	5.7	5.2	4.6	.....	.....	.....	13
8	7.8	7.5	7.2	6.8	6.4	6.0	5.5	4.7	.....	.....	22
9	8.8	8.4	8.0	7.6	7.2	6.6	6.0	5.3	.....	.....	.....
10	9.8	9.2	8.8	8.5	8.0	7.3	6.6	5.9	.....	.....	50
11	10.8	10.0	9.5	9.0	8.4	7.6	6.8	6.0	5.2	4.5	50
12	11.6	10.8	10.2	9.6	8.8	8.0	7.1	6.2	5.4	4.6	51
13	12.6	11.6	11.0	10.3	9.4	8.5	7.5	6.5	5.6	4.7	17
14	13.5	12.5	11.8	11.1	10.3	9.3	8.1	7.0	5.9	4.9	9
15	14.5	13.4	12.7	12.0	11.1	10.0	8.8	7.5	6.3	5.1	9
Total	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	221

TREES 70 FEET IN HEIGHT.

Diameter breast high.	Height from ground.												
	5 feet.	10 feet.	15 feet.	20 feet.	25 feet.	30 feet.	35 feet.	40 feet.	45 feet.	50 feet.	55 feet.	60 feet.	Basis.
Inches.	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*Trees.*
10	10.1	9.3	8.8	8.5	8.1	7.7	7.1	6.5	5.8	5.1	4.5	3.8	50
11	11.1	10.1	9.6	9.2	8.7	8.2	7.7	7.0	6.3	5.5	4.8	4.0	50
12	12.1	11.0	10.3	9.8	9.3	8.7	8.2	7.5	6.8	5.9	5.1	4.1	49
13	12.9	11.9	11.1	10.5	9.9	9.3	8.7	8.0	7.2	6.3	5.4	4.3	50
14	13.8	12.7	11.9	11.2	10.5	9.9	9.2	8.5	7.6	6.6	5.6	4.5	50
15	14.8	13.5	12.6	11.9	11.2	10.5	9.7	8.9	7.9	6.9	5.8	4.7	42
16	15.8	14.5	13.5	12.7	11.9	11.2	10.3	9.4	8.4	7.2	6.1	4.9	16
17	16.9	15.5	14.4	13.5	12.6	11.8	10.9	9.8	8.7	7.5	6.3	5.1	12
18	17.9	16.4	15.3	14.3	13.3	12.4	11.3	10.2	9.0	7.7	6.5	5.2	7
19	18.8	17.3	16.0	15.0	14.0	13.0	11.9	10.7	9.4	8.0	6.7	5.4	3
20	19.8	18.1	16.8	15.7	14.6	13.5	12.4	11.1	9.7	8.2	6.8	5.5	2
Total	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	331

[1] The figures for trees 10 inches and over in diameter in the 60-foot height class, and for all trees in the 70, 80, and 90 foot height classes were originally published in Forest Service Circular 126, and are based on data secured in Gallatin County, Mont. The figures for all trees in the 50-foot height class and for the 7 and 8 inch trees in the 60-foot height class are based on data secured in Deerlodge County, Mont. The figures for 9-inch trees in the 60-foot height class are interpolated.

TABLE 29.—*Stem taper of lodgepole pine as shown by diameter inside bark, Gallatin and Deerlodge Counties, Mont.*—Continued.

TREES 80 FEET IN HEIGHT.

Diameter breast high.	Height from ground.													
	5 feet.	10 feet.	15 feet.	20 feet.	25 feet.	30 feet.	35 feet.	40 feet.	45 feet.	50 feet.	55 feet.	60 feet.	65 feet.	Basis.
Inches.	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*Trees.*
10	9.7	9.1	8.8	8.6	8.3	7.9	7.5	7.1	6.6	6.0	5.4	4.8	4.3	50
11	10.7	10.0	9.7	9.4	9.0	8.6	8.1	7.6	7.0	6.4	5.7	5.1	4.4	50
12	11.8	10.9	10.5	10.1	9.7	9.2	8.7	8.1	7.5	6.8	6.0	5.3	4.6	50
13	12.7	11.8	11.3	10.8	10.4	9.9	9.4	8.7	8.0	7.2	6.3	5.5	4.8	47
14	13.7	12.7	12.1	11.5	11.0	10.5	9.9	9.2	8.4	7.6	6.7	5.8	4.9	41
15	14.7	13.6	12.9	12.3	11.7	11.1	10.5	9.7	8.9	8.0	7.0	6.0	5.1	38
16	15.8	14.6	13.7	13.0	12.4	11.8	11.1	10.3	9.4	8.4	7.3	6.2	5.2	28
17	16.8	15.4	14.5	13.8	13.1	12.4	11.6	10.7	9.8	8.7	7.6	6.4	5.3	20
18	17.8	16.3	15.3	14.5	13.8	13.0	12.2	11.2	10.2	9.1	7.9	6.7	5.5	10
19	18.7	17.1	16.0	15.1	14.3	13.5	12.6	11.7	10.6	9.4	8.2	6.9	5.6	10
20	19.6	17.9	16.7	15.7	14.8	14.0	13.1	12.1	11.0	9.7	8.4	7.1	5.7	2
Total														346

TREES 90 FEET IN HEIGHT.

Diameter breast high.	Height from ground.															
	5 feet.	10 feet.	15 feet.	20 feet.	25 feet.	30 feet.	35 feet.	40 feet.	45 feet.	50 feet.	55 feet.	60 feet.	65 feet.	70 feet.	75 feet.	Basis.
Inches.	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*Trees.*
12	11.8	10.9	10.6	10.4	10.1	9.8	9.4	8.9	8.4	7.8	7.2	6.5	5.7	4.8	.....	16
13	12.8	11.9	11.5	11.2	10.9	10.5	10.1	9.6	9.1	8.4	7.8	7.1	6.3	5.3	4.3	10
14	13.8	12.9	12.4	12.0	11.7	11.3	10.8	10.3	9.7	9.0	8.3	7.5	6.7	5.8	4.7	3
15	14.8	13.8	13.2	12.8	12.4	12.0	11.5	10.9	10.3	9.5	8.8	8.0	7.1	6.1	4.9	21
16	15.8	14.7	14.1	13.6	13.2	12.7	12.2	11.5	10.8	10.0	9.2	8.3	7.4	6.3	5.2	13
17	16.8	15.6	14.9	14.4	14.0	13.5	12.9	12.2	11.3	10.4	9.6	8.6	7.6	6.4	5.3	8
18	17.7	16.5	15.7	15.2	14.6	14.1	13.5	12.7	11.8	10.8	9.9	8.9	7.8	6.6	5.4	6
19	18.7	17.2	16.4	15.8	15.2	14.6	13.9	13.1	12.2	11.2	10.2	9.1	8.0	6.7	5.5	4
20	19.7	18.1	17.2	16.4	15.8	15.1	14.4	13.5	12.6	11.5	10.4	9.3	8.1	6.8	5.6	7
21	20.6	18.9	17.8	17.0	16.3	15.6	14.8	13.9	12.8	11.7	10.6	9.4	8.2	6.9	5.6	2
22	21.6	19.7	18.5	17.6	16.9	16.1	15.3	14.3	13.2	12.0	10.8	9.6	8.3	7.0	5.7	3
Total																93

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